DUELING RADARS: DECEPTION IN THE SKY

highTechnology

COVERING THE BUSINESS OF EMERGING TECHNOLOGY

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AUGUST 1986

SPECIAL REPORT

JAPANWATCH '86

Trends in production, marketing, and R&D

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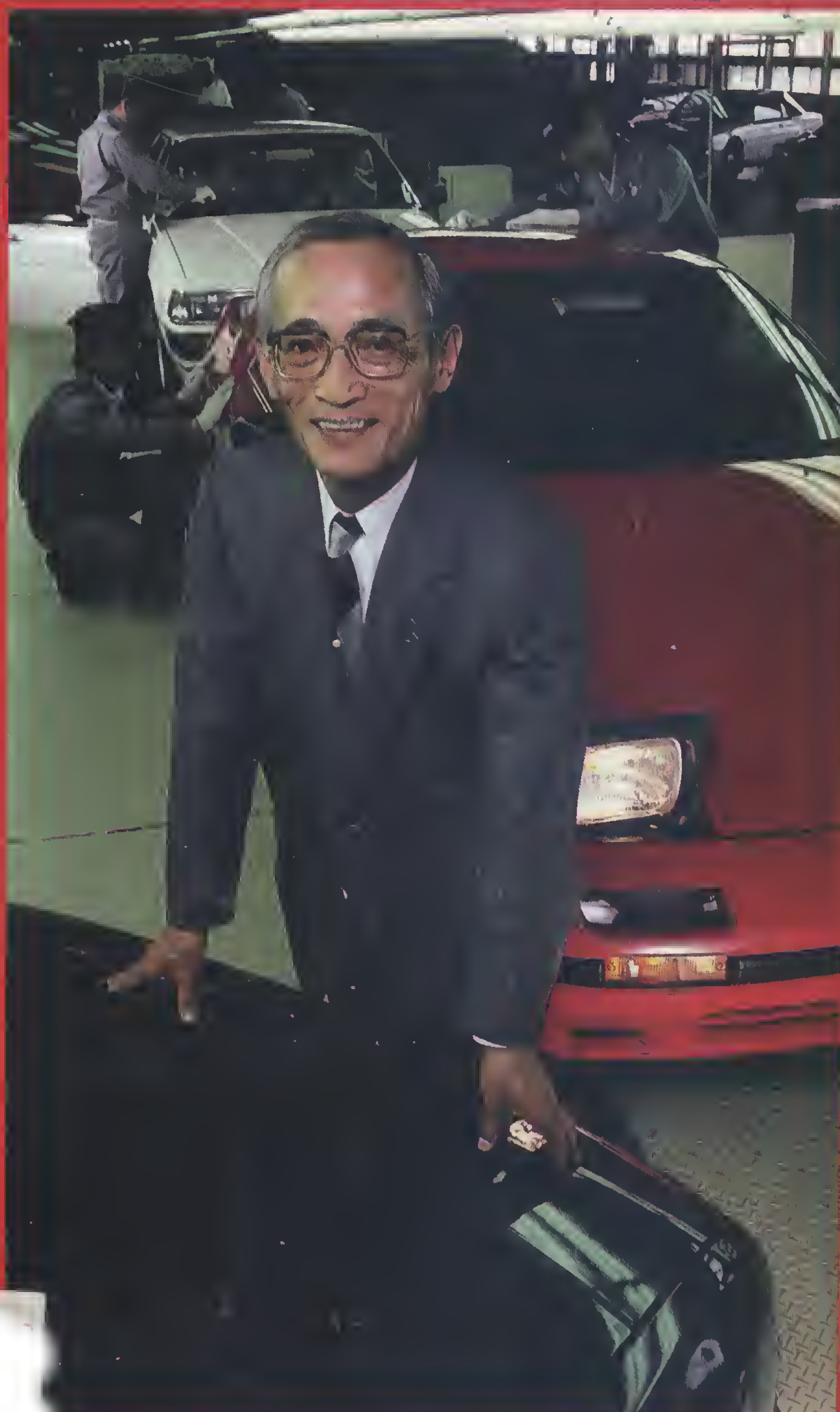
Automobiles
Small engines
Electronics
Software
Composites
Biotechnology
Machine tools
Optical links



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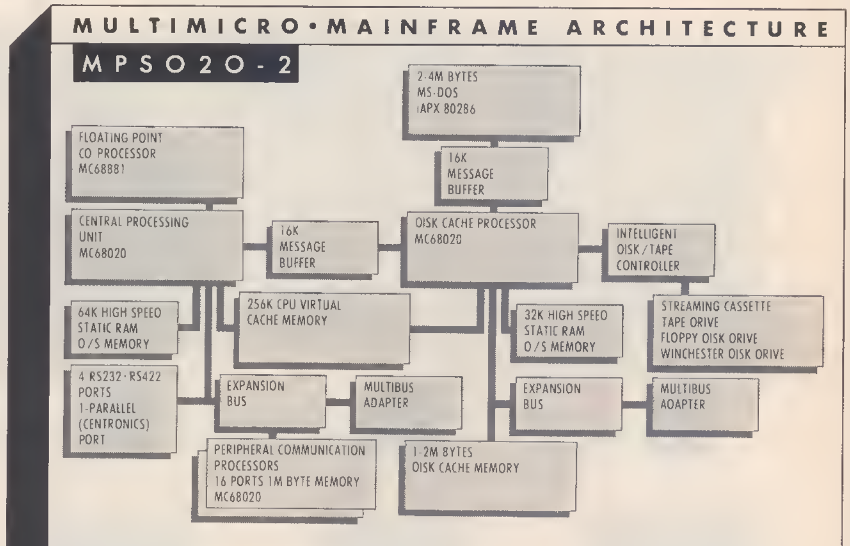

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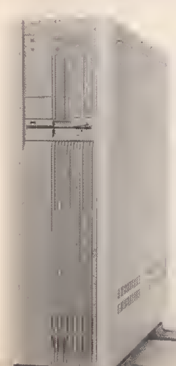

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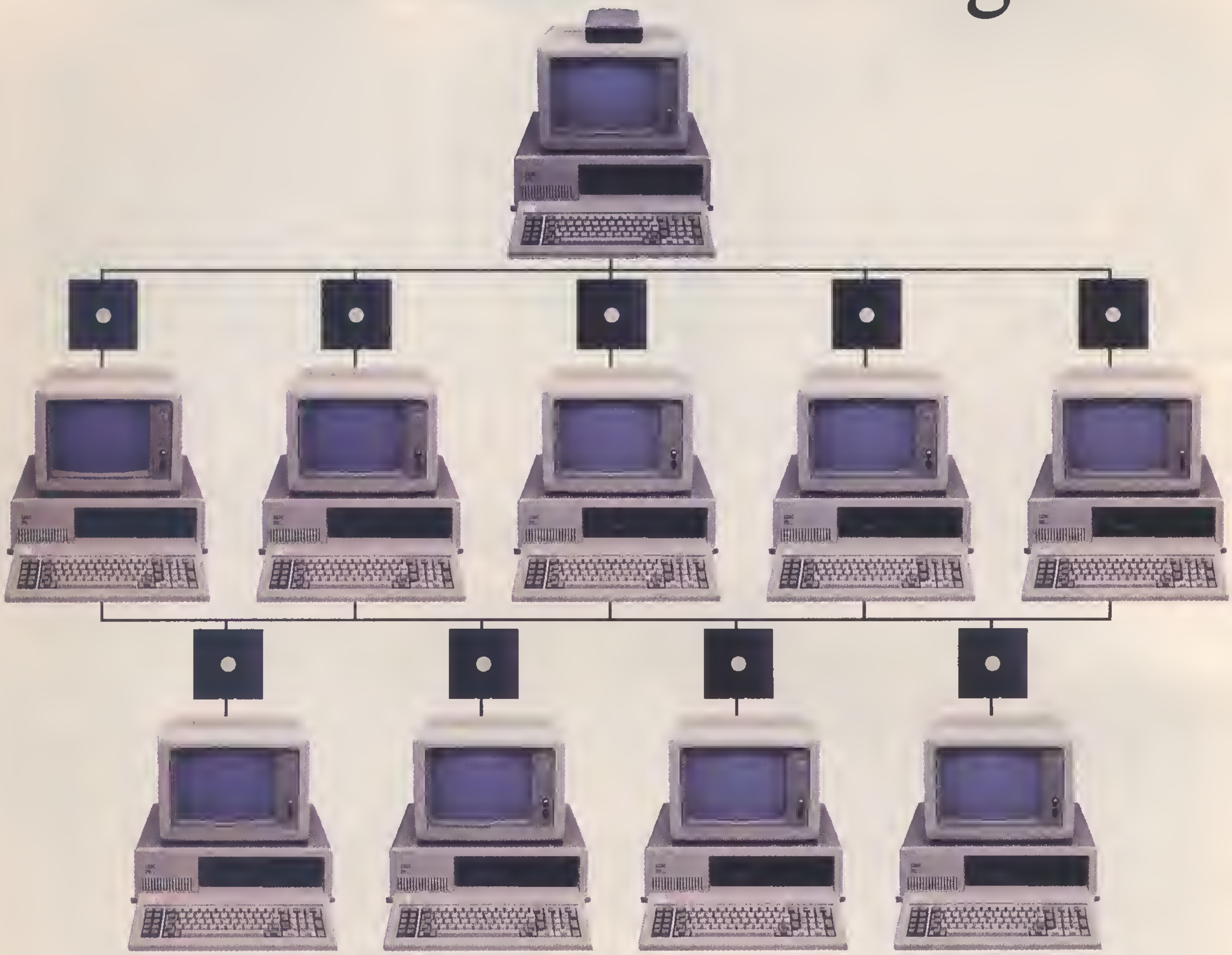

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FEATURES

DEPARTMENTS

OPINION

BRAD HAMANN

The very model of a modern major competitor

Japan, with its huge success in global markets, provides an instructive model for both developing and industrialized nations. How did this island nation with few resources grow from a land of devastation to a world economic power in just four decades?

A dedicated workforce, loyal to both nation and company, was essential. National planning helped: coordinated efforts enabled Japan to move steadily up the technology ladder. "Visions of the future" were created to gain a national consensus, whether for fifth-generation computers or biotechnology. Tax laws strongly favored saving and discouraged borrowing by individuals. This provided the capital needed to build strong industries. Large diversified conglomerates (*zaibatsu*), each including a financing arm, moved into one new market after another. Vertical integration in fast-growth markets, from end-user products right down to the parts and materials needed to make them, added strength. Companies worked together to get up to speed in a technology, but then competed fiercely when global markets developed.

Manufacturing became the foundation for Japan's powerful growth economy. But as the standard of living of the workforce rose, productivity also had to go up to keep factories competitive. Production quality was also vital, to reduce the expense of servicing complex products worldwide.

The intelligent use of off-the-shelf technologies—relatively primitive robots, for example—and cost-saving methods, such as just-in-time systems to keep in-process inventory low, have enabled Japan to make quality products while boosting productivity. Many techniques common in Japanese factories, based on resourcefulness and careful attention to detail, are described in the on-the-scene reports in this issue.

Ironically, the Japanese now face many of the problems they helped create for the U.S. and Europe. Korea and other Asian nations with low wage rates are competing vigorously for markets the Japanese currently dominate, using many lessons learned from Japan. In response, the Japanese, who generally used copycat methods to catch up, now recognize the need to create new technologies to stay out in front. They are trying to emulate some of the conditions, such as strong basic R&D and entrepreneurship, that have made the U.S. a technological innovator.

As the battle for global markets gets even tougher, U.S. and European managers and policymakers would do well to learn from Japan, especially in moving innovative ideas from the labs to the production line and marketplace. The Japanese are willing to put good ideas to work no matter what their source. They sent intelligent, hard-working people to study how Western industries did things, and then made their own improvements. In the old days, that might have been called Yankee ingenuity.

Robert Haavind

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highTechnology

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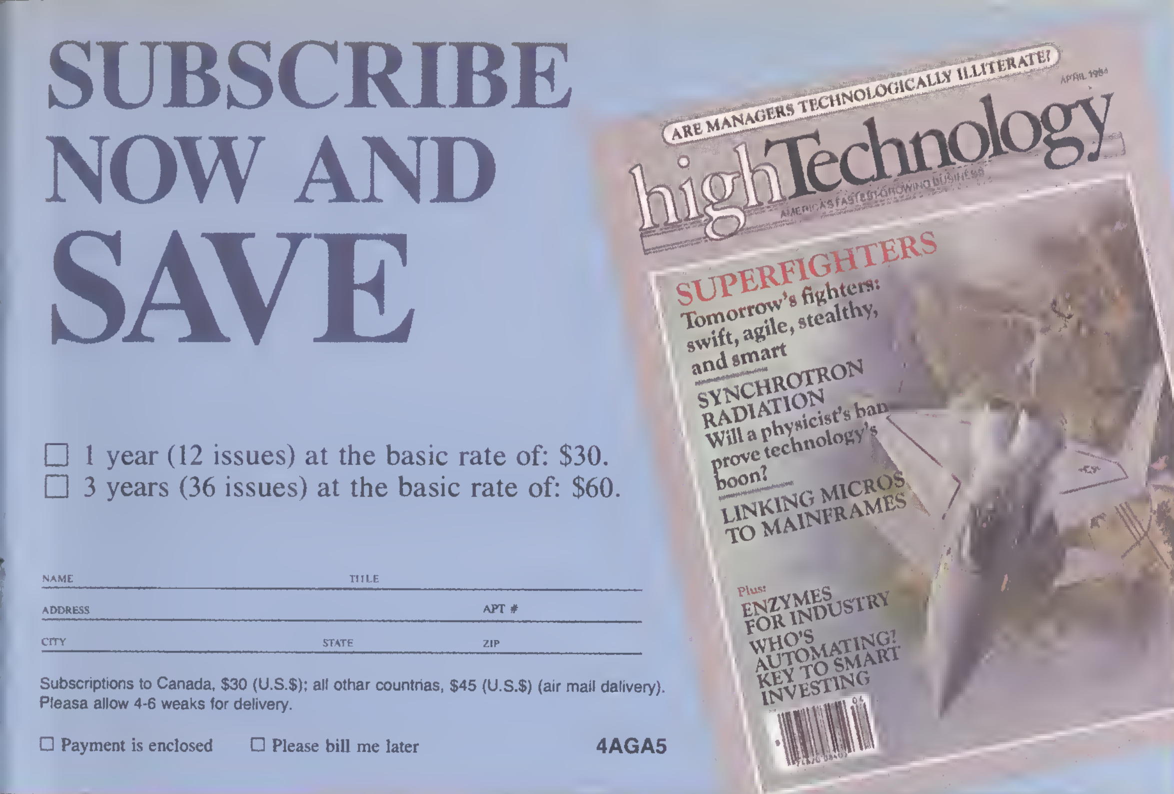

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The various "centers of excellence" programs are no doubt a step in the right direction. The only problem I see with them is that only a few leading schools tend to benefit. Industrial support needs to be much more broadly based.

A. S. Mujumdar
Department of Chemical Engineering
McGill University
Montreal, Quebec

An interesting question is why simple instruction sets are now deemed better than complex ones. One reason is that the type of computations performed are often no longer numerical problems but logical problems. If the computer is still required to do substantial numerical computations, a separate processor is incorporated and the total computer is not a RISC machine.

Another reason is that the construction technology has changed to one of a very few layers of two-dimensional interconnections; this makes it difficult to design and fabricate complex high-performance interconnection networks. The advantages of RISC machines are artifacts of these current con-

A viable and progressive electric utility industry is absolutely essential to technological progress.

C. C. Burwell
Institute for Energy Analysis
Oak Ridge Associated Universities
Oak Ridge, Tenn.

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LETTERS

Industrial support of research universities

I completely agree with the views expressed in "Ivory towers offer golden opportunities" (June 1986, p. 4).

In addition to the probable impact of Gramm-Rudman-Hollings, many states have to reduce their funding of higher education because of the drop in oil prices; and research will suffer. Thus, research universities stand to benefit from whatever support they may gain from industry, whether from contracts, grants, equipment donations, or support of students.

The quality of education is a direct function of the research conducted in universities. Professors engaged in research bring to their classrooms the most recent knowledge, and that is truly the primary function of a university. Faculties that are not doing research can only impart to their students what they learned years before, and that is not progress. Universities cannot fund research by themselves, but need support from all sources; industry is a major one.

In this connection, legislation to establish a National Space Grant College Program, recently introduced by Sen. Lloyd Bentsen and Rep. Mike Andrews, would provide matching federal funds to complement research support by the states and industry. This approach would encourage industry to get involved with universities in the manner that you suggested. The relatively new Space Research Center at Texas A&M has already had some modest success in establishing this kind of involvement.

Frank E. Vandiver, President
Texas A&M University
College Station, Tex.

Congratulations on your editorial urging establishment of industry–university links. The government can catalyze the forging of such links to mutual advantage via suitable legislation and tax incentives. Perhaps such intervention by government is, unfortunately, necessary since industry (with some notable exceptions) views research support to universities as a short-term expense rather than as a long-term investment.

The various "centers of excellence" programs are no doubt a step in the right direction. The only problem I see with them is that only a few leading schools tend to benefit. Industrial support needs to be much more broadly based.

A. S. Mujumdar
Department of Chemical Engineering
McGill University
Montreal, Quebec

The public impact of private networks

Your treatment of new developments in business communications practices in "The bypass connection" (May 1986, p. 21) was thorough and insightful, except for one omission—the impact of privatized communications on the public interest.

There is much debate in the communications-policy field regarding the merits of private communications networks, but ultimately it boils down to one thing. Business users no longer want to share the cost of maintaining the public telecommunications network, even though it is they who make the greatest use of the network and realize the greatest financial returns from that use.

Without carrying a brief for the local telephone companies, whose performance has left something to be desired, one can still be concerned that the burden of public telecommunications—the "glue" of a democratic society—is being shifted to those least able to support it, through bypass and the consequent revenue adjustments.

Robert Jacobson
Principal Consultant
Assembly Committee on Utilities and Commerce
California Legislature
Sacramento, Cal.

The RISC window

I enjoyed your article "A simple path to computing" (June 1986, p. 28), but would like to add a few comments.

The early electronic computers had limited instruction sets because of component reliability problems and the difficulties of handling complex designs. As advances were made in these areas, the instruction sets increased in complexity in order to improve the performance.

An interesting question is why simple instruction sets are now deemed better than complex ones. One reason is that the type of computations performed are often no longer numerical problems but logical problems. If the computer is still required to do substantial numerical computations, a separate processor is incorporated and the total computer is not a RISC machine.

Another reason is that the construction technology has changed to one of a very few layers of two-dimensional interconnections; this makes it difficult to design and fabricate complex high-performance interconnection networks. The advantages of RISC machines are artifacts of these current constraints, and will cease to exist when advances in these technologies again enable the exploitation of more complex designs.

Martin Graham
Department of Electrical Engineering and Computer Sciences
University of California
Berkeley, Cal.

Not a CAD/CAM company

Congratulations on your excellent article "Engineering without paper" (March 1986, p. 38).

I would like to point out, however, that contrary to our inclusion in the box "The up-and-comers in CAD/CAM tools," Cognition is not and does not plan to become a full-line CAD/CAM supplier, nor does it offer a solid-modeling system. Cognition, in fact, is the first company to offer an integrated mechanical computer-aided engineering system. We do intend, however, to provide systems whose outputs will electronically link to CAD/CAM systems built and sold by others.

Philippe Villers, President
Cognition
Billerica, Mass.

Energy for the steel industry

One aspect of your otherwise excellent article "New life for steel" (April 1986, p. 46) begs comment. Namely, the source of energy that underlies and buttresses technical progress in the steel industry—whether for the arc furnace, direct reduction of ore, continuous-casting machines, rolling operations, or computerized process control—is a plentiful supply of low-cost electricity.

A viable and progressive electric utility industry is absolutely essential to technological progress.

C. C. Burwell
Institute for Energy Analysis
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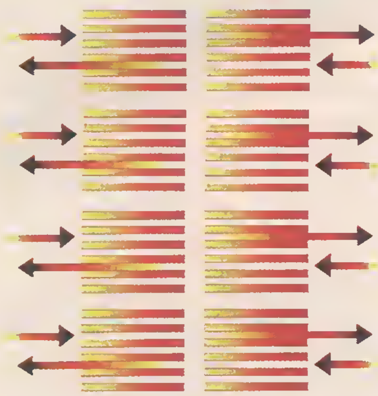

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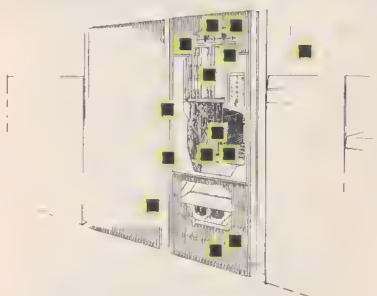

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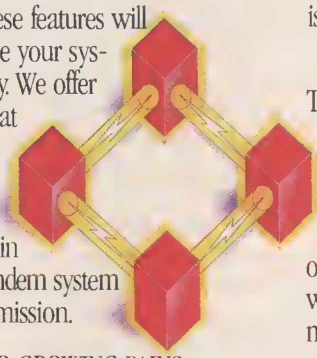

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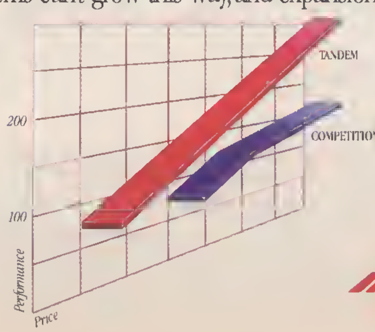

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UPDATE

Trade missions to China

Although the People's Republic of China opened its doors to United States trade nearly 10 years ago, it's still difficult for most high tech companies to establish business relationships there. Aside from the obvious language and cultural differences, just finding the appropriate officials in the world's most populous country is a dizzying task—especially since purchasing authority is often decentralized.

To help telecommunications, electronics, and software companies make those contacts, the Department of Commerce is sponsoring an annual series of trade missions. Each two-week trip is limited to one or two representatives apiece from no more than 20 companies and consists of meetings with high-level officials in three Chinese cities.

Last May, for example, executives from 12 software and electronics companies visited officials in Beijing, Chengdu, and Shanghai, led by George T. DeBakey, deputy assistant secretary for science and electronics in the Commerce Department's International Trade Administration. While it's still too soon to know the outcome of that trip, says DeBakey, "business has already been generated" from a telecommunications mission last December.

Three more trips are planned for 1987: one in February for makers of semiconductor manufacturing equipment, another in April for telecommunications companies, and the last—at a still-undecided date—for software companies.

Two cheers for food irradiation

Proponents of food irradiation recently gained important ground. Responding to petitions by food processors and irradiation companies, the FDA expanded the list of foods approved for treatment to include all fruits and vegetables. The maximum permitted dosage of gamma radiation is still relatively low—100 kilorads. That's enough to kill insects and keep produce fresh for 3–5 days longer, but a far cry from the bacteria-destroying 1000 kilorads that could dramatically extend the shelf life of meat, fish, and poultry.

Although the FDA's April ruling is expected to bring irradiation companies some business from importers of mangoes and other fruits whose usual pesticides have been banned, extensive use of the treatment is not expected soon; the process currently adds 1–3¢ to the cost of a pound of produce. Previously approved foods generated only $2 million worth of business last year, primarily for herbs and spices. But irradiation industry sources say the decision could provide the incentive to pursue their ultimate target—irradiation at germicidal levels—with renewed vigor.

In this effort, says industry analyst Bahar Gidwani of Kidder, Peabody (New York), the irradiation firms must clear several hurdles: they must determine the appropriate dosage for each food, win federal approval, and overcome consumer and food-industry resistance. (Some public interest groups, such as the Health and Energy Institute in Washington, D.C., oppose food irradiation on the grounds that not enough is known about the effects of eating the treated food. The FDA, meanwhile, maintains that although some chemical byproducts are created, the amounts are too small to be a danger.) But if the industry overcomes these obstacles, says Gidwani, food irradiation could become a billion-dollar market by the mid-1990s.

Transistors transformed

An innovative transistor made of amorphous (noncrystalline) silicon may solve the speed problem that plagues other devices of similar composition. Amorphous silicon is attractive for thin-film transistors because it can be deposited inexpensively over large areas, but the resulting devices have been able to handle only relatively weak currents. The DIFET (double injection field-effect transistor), developed by Energy Conversion Devices (ECD) in Troy, Mich., can control currents 20 times as strong. As a result, it could charge capacitors, such as those used to switch memory or display elements, 20 times as fast.

In the DIFET, as in any field-effect transistor, current flowing within a silicon channel is switched on and off by an electric field from a "gate" terminal. In conventional devices, however, a contact supplies a current of either electrons (–) or holes (+), depending on how it is doped. The trouble is that the concentration of like charges sets up an opposing field that partly cancels the gate voltage, severely limiting the amount of current that can be controlled. To avoid this problem, ECD connects the channel to two contacts, one supplying electrons, the other supplying holes. Thus, when a positive voltage is applied at the gate, electrons are drawn into the channel, and the resulting

negative charge in turn attracts holes. The two types of charge carrier neutralize each other, so they can flow through the channel without producing the undesirable counterfield.

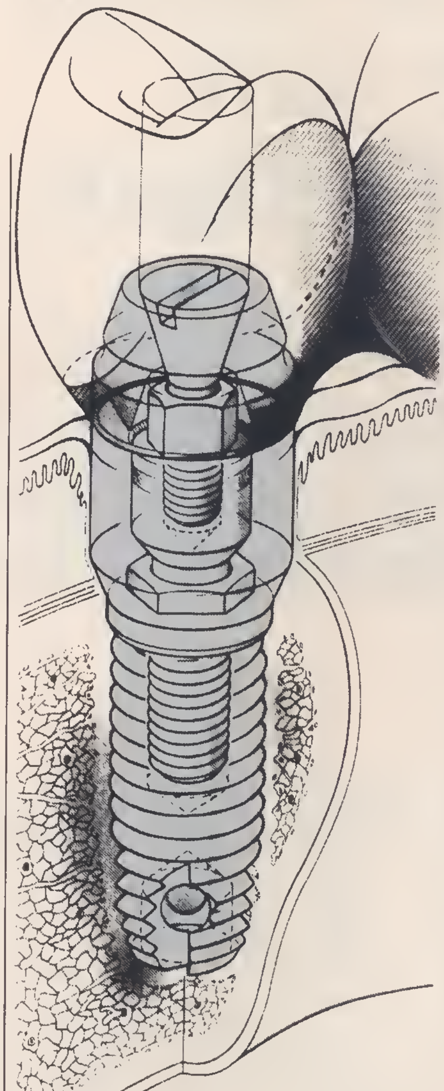
ECD has operated a prototype and filed for patents. "This is a major advance" for thin-film transistors, says Univ. of Illinois (Urbana) professor emeritus John Bardeen, who shared the Nobel Prize for the invention of the transistor.

Permanent dentures with bioactive materials

A process developed by a Swedish surgeon offers a permanent alternative to painful or ill-fitting dentures. Tradenamed Biotes, the process and materials are now being marketed by Nobelpharma (Waltham, Mass.). The company also trains oral surgeons in the technique at 15 U.S. sites.

In the Biotes system, recently given "provisional approval" by the American Dental Association, several titanium screws about 4 mm in diameter are inserted into the jawbone. Through a biochemical process known as osseointegration, which is not yet fully understood, a permanent, mechanically stable bond forms between the bone and the thin layer of titanium oxide that results when the insert is exposed to air. A few months later, after the tissue has fully healed, a bridge containing false teeth is secured to the screws.

The procedure has been performed on several thousand patients worldwide, says inventor Per-Ingvar Branemark, with an average success rate of more than 90%. Clinical data suggest that the dentures will remain firmly fixed for 20 years or more.



In the Biotes denture process, bone bonds firmly to titanium screws.

Nobelpharma sees a large U.S. market for Biotes. According to the company, some 30 million Americans have no teeth in one or both jaws, and about a tenth of them cannot wear dentures for physical or psychological reasons.

Mixed outlook for technical education

Graduate enrollment in science and engineering is on the verge of decline, according to the latest statistics from the National Science Foundation (NSF), but a study by the congressional Office of Technology Assessment (OTA) suggests that shortages are not inevitable.

Graduate enrollment in science and engineering grew 2% a year during 1977–83 but showed virtually no growth in 1984—when there were 415,000 such students (247,000 full-time) enrolled in U.S. schools—and similar findings are expected for 1985. Soon, reports the NSF, enrollment could actually decline. The U.S. population of 18- to 24-year-olds will fall from 30 million in 1982 to 24 million in 1995, and a larger proportion of this group will be blacks and hispanics, who have been only half as likely as whites to become scientists or engineers.

But according to the OTA, other factors could partially offset these declines. College enrollment among 25- to 44-year-olds—which has risen steadily over the past decade, now accounting for 20% of all undergraduates—could well continue to increase as this age group expands over the next several years. And the mounting demand for scientists and engineers will make these professions more attractive to high school and college students "and convince more of those with degrees to work in the field," says OTA study director Gene Frankel. (Currently only 7% of the college-age population receive undergraduate degrees in science or engineering, and only two-thirds of those go on to work in related areas.)

Still, the OTA sees no room for complacency. In particular, it recommends that industry and government encourage more blacks, hispanics, and women to enter technical fields.

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Profit Points

—Did you know?—

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- Hawaii ranks 4th in the U.S. in percentage of college-educated individuals in the workforce.
- University of Hawaii electrical engineers ranked first and second in a national recruiting campaign conducted recently by Motorola.
- Of all college students studying Japanese in the U.S., one in three is at the University of Hawaii.

Windows on Japan

Bruce F. Rubinger
Director of Studies
Global Competitiveness Council, Inc.

Not all good ideas are invented here. Because significant technological and economic progress is being made by other countries, particularly Japan, it behooves American companies to monitor advanced research abroad and analyze the latest foreign technologies.

Japanese firms have long understood the wisdom of such practices. They constantly study the global chessboard to identify technological opportunities at an early stage. Meanwhile, most U.S. firms muddle along with policies that are reactive and superficial. A recent survey by the Global Competitiveness Council (GCC) found that only three of 24 high tech firms interviewed actively follow Japanese technology. Despite evidence to the contrary, many companies continue to believe that the superiority of American technology obviates the need to monitor technical progress abroad; that Japanese firms are ultra-secretive; and that Japanese research is not as creative as that in the West.

American firms could, in fact, benefit substantially from timely information on new products, processes, joint-venture opportunities, and emerging technologies in Japan. And despite common perceptions, there is a wealth of information in Japan—in the form of trade publications, databases, trade shows, conferences, newsletters, patents, government studies, corporate journals, and securities filings—available to the public.

GCC has used a variety of public information sources for studies of Japanese technology, for generating profiles of potential joint-venture partners, and for assisting high tech start-ups in ascertaining whether similar products are already available. What follows is an overview of some of these key Japanese sources.

There are several important newspapers covering the high tech scene, including the *Dempa shimbun* (*Japan Electronics News*), *Nikkei sangyo shimbun* (*Japan Industrial News*), *Nihon kagaku shimbun* (*Japan Chemical News*), and the *Nihon keizai shimbun* (*Japan Economic Journal*).

Business developments of interest to managers are covered by two Japanese-language database services, NEEDS-IR and HINET. The NEEDS-IR database covers three Japanese trade newspapers, 13 trade magazines, and about 1000 general-circulation magazines, making it probably the most comprehensive way to follow business issues in Japan. HINET indexes and abstracts articles from five Japanese industrial newspapers. It also indexes the titles of articles from about 850 magazines with a more technical emphasis than those in NEEDS.

The most comprehensive source of Japanese technical information is the Japan Information Center of Science and Technology (JICST). The working collection of JICST covers approximately 4000 Japanese journals and 6800 foreign journals. Searches of the database must be formulated in Japanese, and the results are printed in Japanese. JICST's coverage also includes conference papers, which are often the earliest sources to report technical advances. This vital resource is almost invariably ignored by Western abstracting and indexing services.

Reports by industry associations and publishing firms represent another important source of information. English-language annual publications include *Computer White Paper*, *Electronics in Japan*, *Market Share in Japan*, and *Japan Electronics Almanac*. The four volumes of the *Japan Electronics Buyers' Guide* covers the makers, sellers, and overseas affiliates of companies engaged in production of electronic components, consumer electronics, computers for engineering applications, and office electronics. Under manufacturers, for example, it lists the names of the officers and key sales personnel, factory locations, financial information, trade names, and principal products.

Japanese-language annual publications include *Computer hardware kaisha rodu* (*Computer Hardware Company Handbook*), *Denshi kogyo nenkan* (*Yearbook of the Electronics Industry*), *Nihon handotai nenkan* (*Japan Semiconductor Annual*), *Joho shori software kaisha roku* (*Information Processing Software Company Handbook*), and *OA nenkan* (*Office Automation Annual*). The latter is representative of the detailed industry information these publications provide. Its coverage includes a description of recent trends in office-automation sales by equipment type, the prospects for the year, recent implementation experience, and networking issues.

There are also a number of English-language newsletters and monthly publications covering aspects of the Japanese high tech scene. *Dempa Digest* is a weekly 12-page summary of articles from *Dempa shimbun*. Dempa Publications also puts out several monthly publications in English: JEI—the *Journal of the Electronics Industry;* JEE—the *Journal of Electronic Engineering;* and AEU—the *Journal of Asia Electronics Union.*

There are several independent English-language newsletters that, although very general, provide information not readily available to Americans. These include *Techno Japan*,

The Global Competitiveness Council, Inc., is a high tech research and management advisory company in Boston.

ELECTRO *Data Net, The Japan Mechatronics Letter,* and *Japan High Tech Review.*

Companies themselves may also be good information sources. Many Japanese firms publish house organs, which sometimes appear in English-language versions, as in the case of *Fujitsu Technical Journal, Fuji Electric Review, Hitachi Review,* and *Hitachi Technology.* However, the Japanese-language editions tend to be published more frequently and have greater depth.

Finally, GCC recommends that firms cover trade shows and conferences in Japan. Some, such as the annual Office Automation Show and Software Show, are readily accessible to Americans without a command of Japanese. But Japanese-speaking individuals obviously have a far broader range of meetings from which to choose. These include Mechatronics Japan, Softopia Tokyo (computer software), the CAD/CAM/CAE Show, Microcomputer Show, Industrial Robot Show, the New Technology Show, and regional high tech trade shows.

Japan is the single most important foreign source of advanced technology. Although extensive information exists on Japanese progress, U.S. firms generally lack the infrastructure to benefit from it. Because much of this information is in Japanese and poorly indexed, the actual task of acquiring, sifting, and analyzing this knowledge base is best left to outside firms with specialized skills. However, only the high tech company itself can structure the search and integrate the resultant knowledge into its decision-making process.

These tasks can be facilitated by "technological gatekeepers" who serve as bridges between the company and the outside world of technology. Companies such as GE and Exxon have created such a position, which they call director of technology assessment. But although it is the gatekeeper's job to access external sources directly—through interactions with vendors, university and corporate labs, and consultants, for example—the entire firm must be drawn into this process.

In the present era, change is inevitable, rapid, and of global scale. To compete effectively, U.S. industry must respect the technical progress taking place abroad, value "external learning" as highly as internal R&D, and create companywide mechanisms to profit from this knowledge. Survival requires adaption. □

BUSINESS STRATEGIES

Du Pont:
MOVING INTO MEMBRANE FILTERS

Membrane filter systems, used to separate substances in solution, are just starting to climb the steep part of the classical S-shaped curve of technologies, says Hugh Knipmeyer, technical manager of Du Pont's new membrane products division. Du Pont expects that today's $500 million worldwide market will grow to $2–3 billion in sales by 1995, says Robert Sievers, the company's director of membrane products.

The company's first membrane product, introduced 15 years ago, was the Permasep permeator used for water purification in projects such as the $10 million plant Du Pont recently announced it will build in Saudi Arabia. But it wasn't until 1978, when the company developed its second commercial product, Nafion—used to produce chlorine and caustic soda in electrolytic cells—that it began building a core technology that could be applied to other areas, says James Wilbur, an analyst for Smith Barney Harris Upham (New York). Today, Du Pont is far from being the only large company in the membrane market. Although "it's been dominated in the past by small organizations," says Wilbur, "now we're seeing more of the large chemical companies."

Shortly after consolidating all inhouse membrane R&D into the new division this spring, Du Pont announced its third membrane product, a system that separates process hydrogen from waste gases in refineries. This hydrogen—crucial to a variety of refinery processes that range from removing sulfur from crude oil to improving fuel octane—would ordinarily be lost. Du Pont's aim is "to recover it and reuse it in the refinery process," explains Knipmeyer.

At the heart of the company's recovery system is a series of tiny hollow tubes made of fiber membranes. The small molecules of the more permeable hydrogen gas pass through the membranes into one collection chamber, while the larger molecules of gases like methane are channeled into another chamber. A pilot system running since April 1985 at a refinery owned by Conoco (a Du Pont subsidiary) in Ponca City, Okla., can recover as much as 90% of the waste hydrogen in a stream consisting of 75% hydrogen—and can then deliver it back to the refinery in a 98% pure stream. Systems will be priced at $150,000 to $4 million, depending on the volume of gas, the percentage of hydrogen recovered, and the final stream's purity.

Sievers estimates that the market for hydrogen separation systems will reach $800 million by 1995, fueled by a "worldwide demand for hydrogen in refining expected to nearly double by the year 2000." The new division is already considering the development of other membrane-based gas separators, such as one to separate the oxygen and nitrogen in air and another to purify natural gas by removing carbon dioxide.

Although membrane technology has many potential applications, capturing a slice of the business "is not going to be easy" even for a company the size of Du Pont, cautions William Young, an analyst for Drexel Burnham Lambert (New York). The membrane market has become "a crowded field." This prospect doesn't seem to faze Sievers, who reports that the company has already embarked on a new project to explore using membranes to concentrate orange juice, under an agreement with FMC, a leading supplier of equipment and chemicals to the citrus industry. Membrane applications in the food and beverage industry could account for revenues of $150 million by 1995, he predicts. Between this market segment, gas separation, and water purification, Du Pont hopes it can generate enough business to justify its investment in membrane technology.

—Paul Raeburn

MIPS Computer Systems:
TAKING A RISK ON RISC

The computer scientists who first proposed reduced instruction set computer (RISC) architecture were essentially heretics. They believed that computers could make a quantum leap in processing speed if their central processors were greatly simplified, whereas the orthodox view held that the more complex the functions built into a central processor, the more powerful—and the faster—the computer. RISC advocates argued that these complex functions could actually be performed much faster, on the average, if broken into several simple, quickly executed instructions (hence the name "reduced instruction set"), because they could be arranged individually in different programs for peak efficiency.

So far, the RISC concept has been adopted by just a handful of manufacturers, although they include heavyweights IBM (in its new PC/RT) and Hewlett-Packard (in its forthcoming Spectrum line). But now, two-year-old MIPS Computer Systems (Sunnyvale, Cal.) hopes to give RISC wider visibility. It is selling a 32-bit RISC microprocessor, the R2000, that can be used as the central processor in a variety of computers and computer-based equipment. Rating the chip's top speed at 10 million instructions per second (MIPS—an abbreviation the company adopted as its name), the company claims the R2000 operates two to five times as fast as orthodox 32-bit chips from the leading high-performance microprocessor makers Motorola and National Semiconductor.

This speed, says MIPS president and CEO Vaemond H. Crane, is what gives the small company the clout to compete against the "financial, marketing, and sales muscle" of Motorola and National. Most of the 20-plus companies (including minicomputer maker Prime Computer, engineering workstation maker Silicon Graphics, and office computer start-up The Dana Group) that are now incorporating the R2000 into products on their drawing boards had already deemed conventional 32-bit chips too slow for their purposes, he contends. Until MIPS came along, many had been considering more expensive multiprocessor designs.

In contrast, the R2000 is priced comparably with conventional 32-bit chips and is available with a version of the popular Unix operating system, as well as with other software. Such software, especially the compilers that allow the use of several programming languages, is "as important as the chip itself," says John P. Moussouris, one of the company's founders and head of VLSI development, because it restructures programs written for conventional processors to take advantage of RISC architecture. Also available are support chips (except a final version of one that performs floating-point math, scheduled for next year), which are used with the central processor to create entire systems.

The considerable feat of developing

all these components in just two years can be largely attributed to the RISC design philosophy itself, contends David Patterson, professor of computer science at the University of California (Berkeley) and one of the founding fathers of the RISC concept. Stripped-down chips lend themselves to faster design cycles, he says. "Rather than saying, 'let's put everything we can think of into silicon,' RISC designers like MIPS say, 'let's do fewer of these functions, but do them very fast.' " While skeptics charge that such simplification makes the processors unsuitable for certain complicated applications, Patterson counters that recent design work indicates the opposite: they're being adapted to purposes as diverse as office automation and artificial intelligence (AI). The MIPS chips, for example, will be incorporated into a variety of equipment, confirms Crane, ranging from telephone exchanges to engineering workstations. And they will be used both as central processors and as special-purpose accelerators for such functions as fast manipulation of complex graphics and symbolic processing for AI programs.

Until these machines are actually on the market, says Crane, MIPS will be content to limit its activities to development and sales, leaving manufacturing to any of a half-dozen semiconductor foundries that use compatible technology. But with $22 million in backing from many of the country's most prominent venture capital firms, the company could change its plans easily enough.—***Sarah Glazer***

RICK BROWNE

MIPS is aiming its chips at high-speed processing applications, says president Vaemond Crane.

Interactive Training Systems:
MERCHANDISING WITH VIDEO

Laser videodiscs first found their way into business as part of corporate training programs. What sets them apart from earlier instruction films and videotapes is the added dimension of computer control. Each viewer sets his or her own pace, returning to selected sequences for review or skipping ahead to subject matter of special interest.

Now, many of the companies making interactive instructional systems have branched into a new line of business: producing machines to merchandise retail goods and services. One of the field's pioneers, five-year-old Interactive Training Systems (ITS) in Cambridge, Mass., has already developed several systems of this kind, including one for Sears Roebuck and another for the First National Bank of Chicago (FNBC). Company VP and cofounder David A. Lubin describes them as a natural outgrowth of earlier instructional projects. Understanding the human learning process, he says, is as important in demonstrating a product line as in acquiring a job skill. However, ITS has also added staff trained in marketing.

The new Sears systems, housed in special kiosks in the stores, display curtain fabrics and advertise an array of financial services. The FNBC systems, installed both in the bank's branch lobbies and in freestanding units, explain various individual retirement account offerings. A second system, scheduled for installation late this year, according to bank marketing officer Tom Tremain, will collect data that bank officers can use to open customer accounts.

Although merchandising applications for interactive videodisc machines have only just begun, market analyst Natasha Thomsen of Link Resources (New York) estimates that they will account for almost a quarter of the entire market by 1990. The field is dominated thus far by start-ups like ITS, Digital Techniques (Burlington, Mass.), and Byvideo (Sunnyvale, Cal.), but banking applications have already attracted Diebold, a long-standing manufacturer of banking equipment.

ITS attributes its success so far to a strong background in the education field. Founders Lubin and Harry M. Lasker, both previously on the faculty of the Harvard Graduate School of Education, were also involved in developing the video teaching formats used in *Sesame Street* and *The Electric Company*. Corporate training still accounts for the lion's share of the privately owned company's revenues. An average course costs $100,000 to develop, with the machines used to run them priced at an additional $12,000 apiece. With sales of $9.2 million in 1985, ITS counts IBM, Eastman Kodak, Xerox, J. C. Penney, Aetna, and the Bank of America among its clients.

But the company is looking toward merchandising for much of its future growth. It has contracts with Citibank, First Interstate, and Massachusetts Mutual Life Insurance as well as with the FNBC for systems to promote banking and insurance services. And systems that actually make sales and conduct a variety of financial transactions are just around the corner, contends Lubin. Some machines the company is currently planning will open and close bank accounts and possibly even approve loans. It's a far cry from teaching children the alphabet on *Sesame Street*, but those of us who grew up with television may find it only natural to conduct business with a video screen.—***Patricia Hittner***

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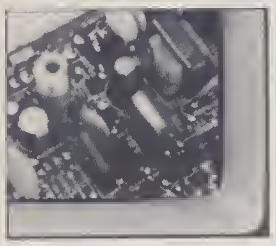

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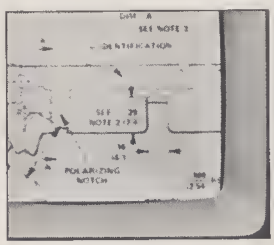

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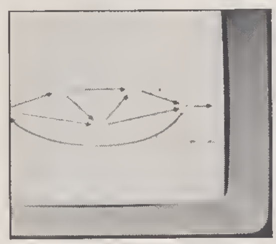

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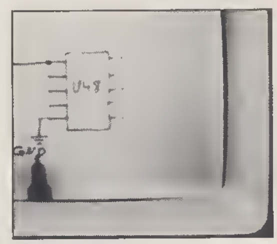

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JAPANWATCH '86

Inventive people never rest: their products could always be better; their work could always be done more efficiently; and their methods, however successful, could always be supplanted by new approaches.

Four HIGH TECHNOLOGY editors recently visited Japan to assess what some of the major industries have on their agendas. In fields where the Japanese are in the technological forefront, such as the auto industry, top priority goes to increasing the flexibility of the production line ("our goal is to manufacture in lot sizes of one"). In industries such as machine tools, where others lead—at least in R&D—the main objective is to define reasonable market niches and make products flexible enough to fill them. In fields where leadership is still up for grabs, such as biotechnology, the Japanese are exploring an unusually wide range of options in order to make rational manufacturing choices later on.

But beyond the ever-increasing sophistication of Japan's factories, the acumen of its industrial decision makers, and the methodical pursuit of new ideas and markets, what most impressed our editors was the attitude behind these enterprises. They unanimously report that a tireless attention to detail—the constant search for small, and not so small, improvements—is what distinguishes Japan from its competitors even more than the quality of its products and the cleverness of its processes. In Japan, technology is not an end in itself but a tool, helping to implement simple and efficient approaches to building the better widget.

Read on, and judge for yourself. □

GOOD IS NEVER ENOUGH

Tokyo—A visitor to Japan doesn't have to go to a factory to see why the country has achieved such great industrial success. The reasons are evident in the thoroughness, efficiency, and resourcefulness that pervade Japanese society. Trains and buses rarely deviate from their schedules by more than a minute or two. Farmers cultivate odd nooks of land, such as the strip formed between a highway and an exit ramp. Store clerks gift-wrap purchases using a method that requires only a single piece of tape. Virtually every door in Tokyo, it seems, slides opens automatically.

Thus, although Japan's ability to produce high-quality goods at low cost has certainly been aided by the widespread use of such technologies as robots, computers, and advanced machine tools, perhaps more important have been a variety of less glamorous practices.

If there is a common creed in Japanese factories, it is this: simplify, simplify. When machine tool maker Yamazaki Mazak set about automating its Minokamo plant, for example, one of the first steps was to lay out every part and every tool used in the current process on two huge tables. Plant engineers were told to walk through this vast array of hardware and justify why each item was needed. Result: the number of tools was reduced from 672 to 46, all but six of which had multiple uses. This approach differs markedly from what usually happens in the U.S., according to Hriday Prasad, manager of industrial control systems at Ford Motor (Dearborn, Mich.) and a frequent visitor to Japanese factories. "An American company would probably try to build a sophisticated database to manage 672 tools," says Prasad.

Even where machines have predominated, they are unexpectedly simple. The vast majority of what the Japanese call robots, for example, don't look much like robots; there's no free-swinging arm that twists on several axes. Japanese robots usually perform the same sequence of motions over and over—such as up, across, down—with little or no ability to adapt their movements to a changing environment. Indeed, these machines would be considered traditional "hard automation" anywhere except Japan.

One reason that simpler equipment suffices is that Japanese companies design their products for ease of manufacture—reducing the number of parts, and ensuring that they are attached in a minimum number of steps. Sony's Walkman II personal stereo, for example, is assembled on a single machine that performs such basic operations as pushing gears onto shafts, turning screws, and applying grease. Hitachi, another champion of this practice, has developed a technique by which engineers can assign a numerical score to their designs indicating how easy it will be to assemble. Hitachi has used this method to simplify the production of such items as audio and video recorders, washing machines, and vacuum cleaners. "It saves the company tens of millions of dollars every year," says Toshiijiro Ohashi, senior planning engineer at the company's Production Engineering Research Lab (Yokohama).

by Herb Brody

Japanese manufacturers maintain tight control over the production process, not only to reduce operation costs (using, for example, the "just-in-time" system developed at Toyota and now employed by most carmakers), but to be able to react quickly to changing market demands—that is, to approach the goal of making products in "batches of one." For such small lots to be economical requires that very little time be lost during tool changeovers. The high tech way to accomplish that goal is with programmable automation—robots and numerically controlled machine tools. While certainly employing such systems where indicated, the Japanese have also focused on streamlining manual processes as well. One motor vehicle manufacturer, for example, shortened lathe setup time tenfold, to about four minutes, by such measures as replacing the slotted screws needed to adjust settings with pins that clipped into place.

Japanese companies often achieve efficiency by making and installing their own automation systems. This practice has several advantages over the more typical U.S. approach, where equipment is purchased from a commercial vendor, often through a third party acting as "system integrator." It avoids the need to show an outsider (the vendor) the company's manufacturing methods, which the Japanese consider highly proprietary. Also, explains Keiichi Asahina, chief engineer of the Tokyo Industrial Technology Center, "companies all think they know their products best" and therefore consider themselves the best qualified to automate their own factories.

Originally propelled by grim necessity—World War II killed many of the country's workers—Japan has been automating steadily and incrementally for three decades.

Left: The Shinkansen, or "bullet train," which reaches speeds of over 100 mph, is a tribute to Japanese efficiency. Like other elements of the country's public transportation system, these computer-controlled trains are rarely more than a couple of minutes off schedule. Below: At Mazda's Hofu plant near Hiroshima, the assembly line is tilted 30° for easier access.

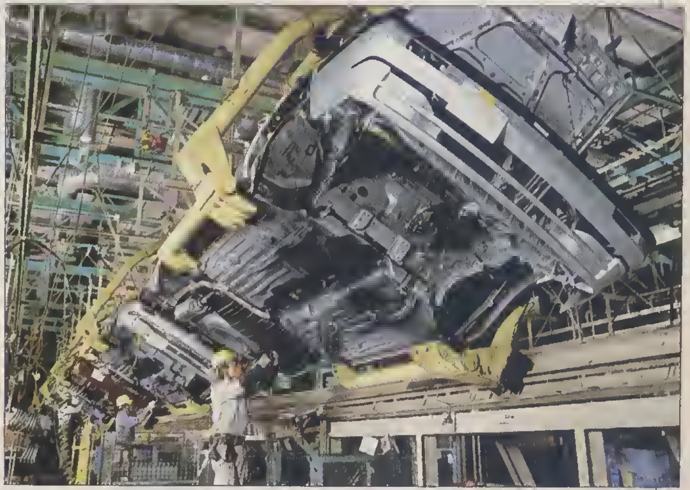
Matsushita, for example, started in 1959 by substituting individual machines for workers. Mechanization of entire production lines didn't start unil the mid-'60s, and factorywide automation not until the early '70s. "We're never satisfied," says Takashi Shiraki, who recently left a management post at Matsushita's factory equipment division in Osaka to head up the similar operation at its U.S. subsidiary, Panasonic Industrial (Elk Grove Village, Ill.). "There is always a higher goal." Matsushita has totally automated assembly of its VCRs, for example, "but it still takes too long to change a machine's instructions."

Japanese companies justify automation according to strict numerical formulas. Nissan Motors, for example, stipulates that the purchase of new factory equipment is warranted only if every 15 million yen ($90,000) of machinery does the job of one worker, according to Tsuneyuki Hane, production control and engineering manager at the Murayama Works near Tokyo. Clockmaker Ishioka Seiko maintains a more conservative threshold of 5 million yen. Japanese companies often allow as long as 5–7 years for the investment in new automation to pay for itself. "As long as there's a consensus in the company that automation is desired, they're willing to wait it out," notes robotics pioneer Joseph Engleberger, who visits Japan regularly. (The founder of Unimation, Engleberger is now head of Transitions Research in Bethel, Conn.).

Machines do not bump workers into the street, because Japanese companies generally hire for life. If the displaced worker has the aptitude, he or she is retrained—perhaps as a robot technician. If necessary, the employee is transferred to another company facility where suitable manual work still exists. A person who insists on staying in the same factory may have to settle for a lower-level job. But automation is not always inevitable, even in high tech fields. The electronics industry, for example, which draws on the large and inexpensive labor pool formed by young women passing between high school and marriage, remains largely manual.

Japanese companies encourage plant-floor workers to offer ideas on how to improve productivity and quality. Worker involvement is high, at least according to company officials. Nissan, for example, reports that 99% of its labor force participates in one of the company's 4000 quality circles—especially impressive given that these groups of about 10 people meet after normal work hours.

Not surprisingly, some suggestions concern job comfort; Toyota, for example, lowered the floor in one section of its Tsutsumi assembly line so workers can apply the side molding onto cars without stooping. But there's also concern for product quality. Ishioka Seiko, which awards bonuses of up to 30,000 yen ($175) for workable ideas, gets an average of 20 suggestions per employee per year, with some employees contributing one a day. A typical example: plastic parts coming out of an injection molding machine were being scratched when dropped into plastic containers. Solution: line the tubs with artificial lawn material (Astroturf) to cushion the impact and reduce scratching.



The high degree of worker involvement in the factory has probably slowed the introduction of computerized communication. "Such automation has been a secondary concern," says Panasonic's Shiraki, "because the workers do such a good job of information management already." Thus while individual computer-controlled machines are common, plantwide networks are not.

This is starting to change, however, as Japan strives to overcome its traditional weakness in computer software. Hitachi, for example, has come up with a common computer language for its robots, machine vision systems, and conveyor mechanisms. Already in use at the company's VCR factory, this language streamlines the flow of information between the various sections of the assembly line. And Toshiba has conceived a structure for tying together all aspects of the factory—from purchasing of parts to control of robot hands—under integrated computer command. By toughening up this last remaining soft spot, Japan's manufacturers threaten to become more formidable than ever. □

HANDS ACROSS JAPAN

SHIMAUCHI—From the mighty arms installing seats and batteries in Nissan automobiles to the nimble machines dropping gears into Seiko watches, robots occupy nearly every corner of Japanese industry. Most of Japan's robots perform such mundane jobs as loading workpieces into machine tools, applying welds to build car frames, and placing components onto circuit boards. While brochures and showrooms display multijointed machines that bristle with sensors, the robots actually used in Japanese factories are typically blind, numb, and capable of executing only a few motions—but they are used to great advantage.

Despite their limitations, these robots are often far more effective than conventional, or hard, automation, since they can be made to move in different ways as the need arises. This adaptability is of particular value to industries such as consumer electronics, where the competitive edge goes to the company that rapidly and continually introduces new products and variations. Hitachi, Sony, and Matsushita, for example, all use robots to build videocassette recorders.

A rotating hand whips any of six tools into working position on the robot Sony uses to assemble VCRs.

Actually, fewer than half of the 200,000 machines that the Japanese claim as robots would meet the more restrictive U.S. definition of the term. The Japanese count as part of their robot population a large number of "pick and place" machines, which usually repeat the same movements; reprogramming is done infrequently because it requires alterations in hardware. By any definition, however, Japan's robot force far outnumbers that of the U.S., which the Robotic Industries Association (Ann Arbor, Mich.) estimates at 20,000.

In addition to shortening the turnaround time on new products, robots enable production in smaller quantities than would otherwise be economical. Brother Industries (Nagoya), for example, exports its electronic typewriters to many different countries and to a variety of user groups—with varying requirements for special symbols—within each country. The many variations lead to lot sizes as small as 10. In order to provide this flexibility, the company uses nine robots to put together the typewriters' mechanical portion—gears, bearings, paper-feed roll, and so forth—and another 16 robots to assemble the keyboard.

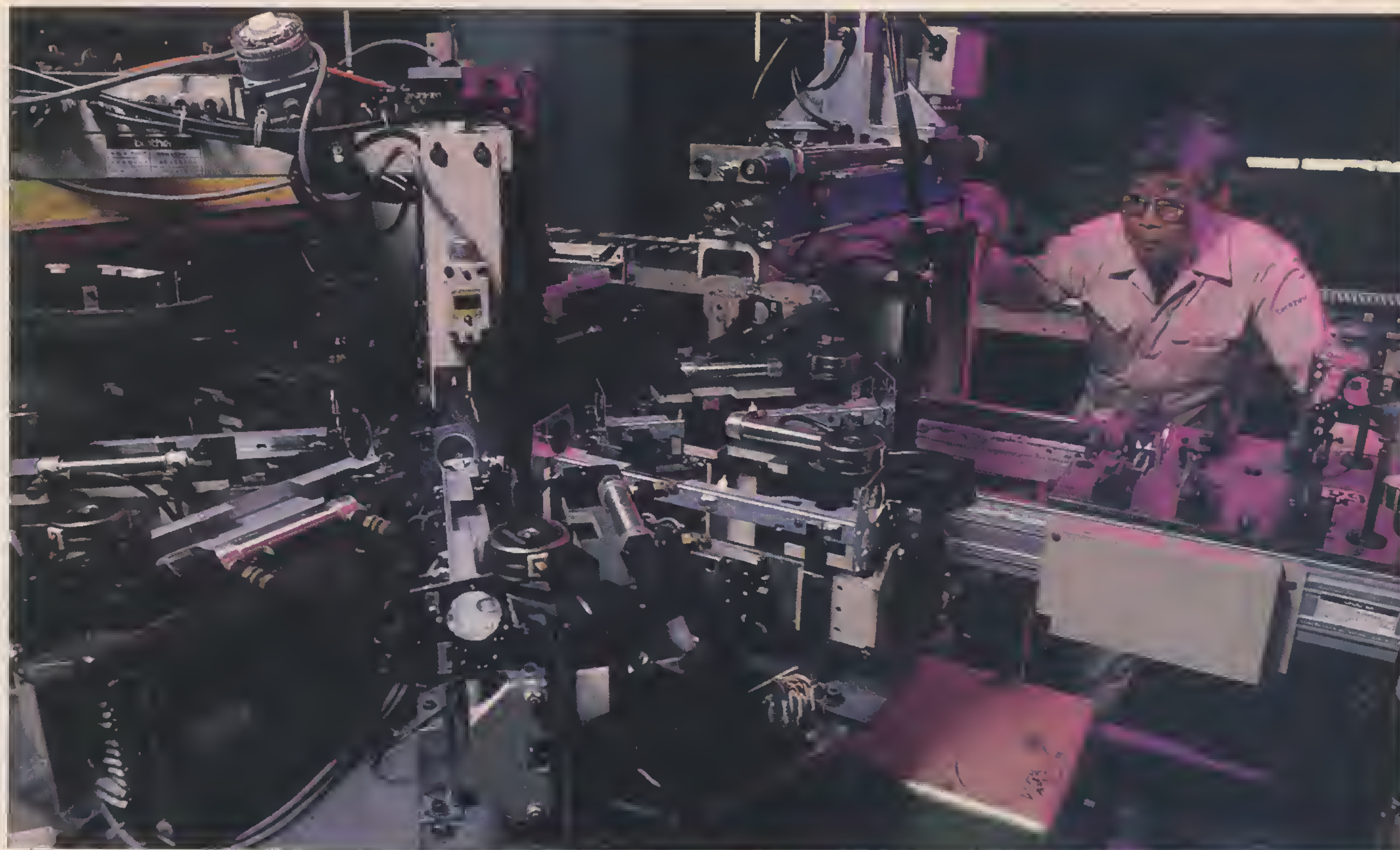
Brother designed and built these robots itself. Such in-house production of manufacturing equipment, which is common in Japan, partly accounts for the relative simplicity of the nation's factory robots. Intended only for a narrow range of applications, these robots lack some of the sophisticated—and expensive—features that commercial vendors add to appeal to a more general market.

An important way that Japanese companies leverage big gains in productivity from limited-function robots is by designing their products so that they can be easily made by machine. For example, parts are machined with flat parallel faces or protruding "handles" that a robot can grasp without trouble. And much attention is devoted to how these components fit together. When Brother automated its typewriter line, the company also redesigned the typewriter so that all the parts could be attached from above. Thus there's no need for a robot arm to wriggle underneath or around the side.

Seiko/Epson (the organization formed last November by the consolidation of Suwa Seikosha and Epson) uses a similar "pileup" design for watches. Since last summer, a 47-robot assembly line has been turning out 100,000 high-end Lassale and Credor brand watches a month. The watches are produced in a mix of styles and variations, in lots as small as 1000, according to Yasunori Yamazaki, assistant engineering manager for robots and factory automation at the company's Shimauchi factory. By year's end, says Yamazaki, the robots will have doubled the number of models in their repertoire.

Each Seiko/Epson robot performs simple movements.

by Herb Brody



LOU JONES

LOU JONES

Clockwise from top: Simple robots assemble Brother's electronic typewriters in lots as small as 10. Seiko Group head Ichiro Hattori with Seiko/Epson's ultraprecise robot, developed to assemble watches and now marketed commercially. In an almost totally unmanned plant near Mount Fuji, Fanuc robots work night and day to make machine tools and other robots.

Typically, it will pick up a part (such as a gear) from one side of its workspace, transport it laterally, then lower it into the partly made watch; the entire operation takes 3–4 seconds. About once an hour a new model of watch starts coming down the line. The robot might then have to prepare itself for a different task—say, by putting down its gripper, dipping its bare wrist into a tool pallet, and attaching itself to a screwdriver. A central computer continuously monitors each robot's actions; upon detecting a problem, the computer orders the robots "upstream" of the malfunction to stop, avoiding a pileup.

The robot does not need to know in advance the exact dimension of the piece it is fetching because, as the gripper closes, the first slight contact with the part trips a touch

sensor; the robot then continues to close for another small increment to assure the grasp. This inexpensive method works as well as more elaborate devices that monitor the force with which the hand is squeezing, according to Yamazaki.

(One operation does require more sophisticated sensing: lining up the watch's slender second hand with the tick marks. During this step, a TV camera trained at the watch face feeds the image to a computer, which measures the distance between the needle-like hand and the mark. The computer generates a signal telling the robot which way to move the hand. Seiko/Epson's sister company, Ishioka Seiko in Ishioka City, makes similar use of vision-assisted robots to place the hands on clocks.)

The watchmaking robots execute their tasks with an almost military crispness. When the hand reaches its destination, it stops with barely a shiver. To increase the robot's speed, Seiko/Epson started from the premise that in a typical assembly operation the robot arm spends most of its time accelerating and decelerating. Thus rather than concentrate on maximizing the robot's peak speed, which is maintained for a very brief period, engineers developed optimal acceleration/deceleration curves that yield the minimum time to move from point to point without a jolt at either end. The robot consults a table of these curves in its memory whenever it makes a move.

When Seiko/Epson decided to robotize its watch operation, no commercially available robots offered the required precision. The company thus proceeded to design and build its own robots, with movements repeatable to within 10 microns—five times as good as what other companies claim for their machines. After successfully deploying them in its own factories, Seiko/Epson began marketing the robots. Customers include top electronics companies at home and in the U.S.—Motorola, NEC, Hitachi, and even archrival Citizen Watch. "We are happy to sell the robots to our competitors," says Yamazaki. "Our secret is in how to use them."

At Seiko/Epson, robot use led to robot *making*. Precisely the opposite has occurred at Fanuc, a Fujitsu subsidiary that ranks second to Matsushita among Japanese robot makers. Fanuc turns its own factories into test-beds. "Using robots in our own plant is a crucial part of our robot development," says chief engineer Shinsuke Sakakibara. "That's the way we find out what improvements to make."

In Fanuc's main factory, near Mount Fuji, robots outnumber the 30 human workers five to one. The robots lift rough metal castings off pallets and load them into computer-controlled machine tools; other robots take the finished parts off the tool and put them onto automatic guided vehicles, which carry the cargo to the trim-shop for painting—by other robots, naturally. Finally, robots assemble the parts into some 30 different types of electric motors. Elsewhere in the factory, workers manually install the motors into bodies to produce about 350 robots a month.

One idea that emerged from Fanuc's test-bed approach quickens robot programming. In the past, a worker had to teach a robot what to do by moving the arm while pressing a button. This tedious process would have to be repeated for every robot operation, even though many were similar. Partly because of complaints from its workers, Fanuc now uses a method whereby they need to program only the ways in which the desired motion differs from a standard one.

Cleverness and resourcefulness, not high-powered technology, seem to govern how the Japanese use robots. Take Mitsubishi Electric's Kani Works near Nagoya, where half a dozen robots assemble switches and starters for electric motors. In one operation, a robot picks up a metal pin and inserts it into a hole in another part; the same claw then rotates 90° and gently taps the pin home with its blunt side, an operation that eliminates the need for an additional machine. Elsewhere in the plant, a subassembly moving down a conveyor needs to be rotated into position for a robot to pick it up. A rigid finger protrudes far enough onto the conveyor to catch the corner of the part, which obediently turns around to the correct orientation. To do the same job, U.S. factories typically use an electromechanical turntable costing thousands of dollars and needing periodic maintenance.

Although most of Japan's industrial robots are of limited skill, more sophisticated machines are starting to appear. A new Sony robot, now being used to assemble VCRs, speeds assembly operation with a multipurpose hand. A pallet containing six different tools is mounted on the robot's wrist. To pick up a screw, for example, the pallet whips around to make a small gripper available for action. The pallet's next rotation might bring the screwdriver into position.

In another small step toward humanlike anatomy, both Sony and Fujitsu have developed robots with two coordinated arms. Thus the left hand can pick up a part and hold it in place for the right hand to work on. Such two-armed robots thus reduce the need for part feeders, positioning jigs, and other peripheral equipment that Fujitsu claims makes up 60–80% of the cost of a typical robotized assembly line. Both companies are already using these robots at their own plants.

A more fundamental leap in robot technology could come out of an ambitious program sponsored by the Japanese government. The Ministry of International Trade and Industry's Electrotechnical Laboratory (Tsukuba Science City) is working on robots that would operate with almost no human intervention. These autonomous robots would probably first be used in nonmanufacturing jobs—principally inspection and maintenance in such hazardous environments as nuclear reactors. Eventually, however, some of the technologies developed for these machines should be useful in industrial robots as well, says Yoshiaki Shirai, director of the lab's automatic control division.

Rather than being bolted to the factory floor, the autonomous robots should be able to move about freely. This will probably require some combination of wheels for level surfaces and legs for stairs and rough terrain. The government's JUPITER project ("juvenescent pioneering technology for robots") is shooting for a robot that ambles along at a humanlike speed of 2.5 mph. None of the many multilegged robots that have been proposed come close to that goal, though, admits Shirai; prototypes have required a full minute to climb up or down one stair. Engineers are also working on a "spider robot," with suction cups enabling it to climb a smooth flat wall at speeds of up to 1.5 feet per second.

To work on its own, a robot should possess visual depth perception. In one experimental technique, lasers project a plane of illumination; the shape of the resulting line of light on the object of interest tells the relative distance to each point across its surface. Such three-dimensional vision, along with finer tactile resolution than is provided by present touch sensors, would be as useful in assembling a complex product as in repairing a leaky pipe, notes Shirai. Moreover, while present robots require detailed instructions for every job, an autonomous machine could respond to a general command such as "assemble"—having in its memory only a blueprint and the dimensions of the parts. □

AUTOMATED AUTOMAKING

HIROSHIMA—Less than 30 years ago, Japan's struggling automakers could barely produce 70,000 vehicles a year, but since the beginning of this decade, Japan has been the world's top manufacturer. In 1985, for example, it produced 12.3 million vehicles, while the U.S. made 11.7 million. In addition, Japan's many auto and truck plants are now considered the world's most efficient, turning out a staggering range of models for a fast-changing domestic market as well as the vastly dissimilar export markets of North America, Europe, the Middle East, Southeast Asia, Africa, and Latin America.

And just as Japan's auto designers apply lessons learned in the home market to the design of export models, its production engineers are exporting their techniques to develop automated assembly plants in more than 40 countries, including the U.S. Indeed, Japanese production concepts—such as just-in-time inventory control, originally developed by Toyota and now in use at most Japanese auto plants—are being avidly adopted by the usually conservative carmakers of the U.S. and Europe.

Japan's motor industry has been much quicker than its competitors to adopt automated techniques, particularly numerically controlled machine tools and industrial robots. Production engineers have taken advantage of the programmability of robots to develop "mixed-model" assembly lines that can produce several hundred variations on a few basic models. As a result, Japanese carmakers can not only change the production mix quickly in response to market demands but also accommodate year-to-year model changes without extensive plant shutdowns and retooling.

Robots have been most extensively applied in repetitive applications such as body painting and spot welding, but they are only slowly appearing on final assembly lines. Often the reasons are simple: installing a wiring harness or a complex, instrument-laden dashboard may call for more human judgment than is possible with conventional robots, or there may be insufficient space on an already crowded assembly line to install robots, their controllers, and the necessary barriers to protect workers and equipment.

One factor that often impedes automation is the need to use existing buildings and equipment installed decades ago. Because much of Japan is mountainous, most of the the country's heavy industries are crammed into the narrow stretch of land along the coast between Tokyo and Osaka; large plots of real estate for new factories are expensive and hard to find. Consequently, plants designed expressly for automation are rare, and automation is often

by Jeffrey Bairstow

Frequent and detailed inspection is a hallmark of Japanese automakers. Here a pair of laser-guided robots inspect newly painted Nissan car bodies in a little over a minute, detecting defects as small as a hundredth of an inch. A comparable inspection by highly skilled workers would take more than 45 minutes.

Japanese autoworkers toe the line

Automation and stringent quality control are only two legs of the "three-legged stool" underlying the exceptional quality of Japanese vehicles. The other leg is the Japanese assembly-line worker, who contributes greatly to production efficiency and quality. The Japanese workers' team attitude, inculcated from nursery school onward, shows in both their efficient on-the-job performance and their frequent suggestions for continual improvements.

At Mitsubishi's Okazaki plant near Nagoya, for example, specially designed carts of tools and parts move along the assembly line under the control of each worker. "This is 'hand-made' automation," says Tadashi Usuki, general manager of production engineering. "The line workers suggested this method and designed the carts."

In the final-assembly line area of minicar-maker Daihatsu's Osaka plant, a wall that is 30 feet long and 6 feet high is covered with charts of production performance by team. The wall also includes quotas for suggestions and a "leadership" table for the best performers. These charts imply more competition among Japanese workers than Westerners commonly suppose, but "it's healthy competition," insists Kazukuni Isihara, assistant general manager of Daihatsu's production engineering department.

In Japanese auto plants, unlike their U.S. and Western European counterparts, work stoppages due to industrial disputes are extremely rare. And workers are often reassigned to the stations where they are most needed, sometimes more than once during a shift, to keep the assembly line running smoothly. Production workers are expected to be competent in several areas and undergo frequent training to maintain their skills. Consequently, reassignments—or the abolition of particular jobs because of automation—rarely pose a problem for management or labor unions.

Given the workers' generally high caliber and management's strong commitment to training, Japanese auto executives may well be under less pressure to automate than their U.S. and European equivalents. Indeed, although robots and other automatic devices are much in evidence in some Japanese auto plants, their overall incidence is less than is popularly supposed. Building cars, particularly on the final-assembly line, often requires the agility and judgment of well-trained workers.

Not only are such workers often more flexible than industrial robots but they also require less capital investment. When it comes to automation, says Hiroshi Nakazawa, production engineering manager for Mitsubishi's Nagoya plants, "we prefer a step-by-step approach that involves the shop floor workers."

applied piecemeal, as needs are perceived. Indeed, lessons learned about factory automation in Japan show up faster overseas. "If you want to see an advanced factory, why don't you go to our Marysville, Ohio, plant?" says Takashi Yanagisawa, director of Honda Engineering Co.

Nevertheless, highly automated car plants are beginning to appear at home. Mazda's Hofu plant, for example, some 50 miles west of its main plant in Hiroshima, was completed in 1982 and occupies about 35 acres on an ocean-front site with its own deep-water loading dock. The plant produces about 20,000 cars a month, more than 60% of which are exported, mostly to the United States. Even with the relative luxury of such a large site, the plant is compactly organized, with the four major shops—metal stamping, body assembly, painting, and final assembly—arranged in the four corners of a rectangle to minimize the transfer and handling of parts, subassemblies, and bodies.

The goal of the Hofu plant, says Mazda president Kenichi Yamamoto, himself a former engineer, is "to achieve productivity twice as high as that of our Hiroshima plant"—a goal that Yamamoto feels is close to being attained. While the plant uses more than 150 robots, Yamamoto points out that much of the increase in productivity comes from improved material-handling methods. For example, all the unloading of parts and subassemblies from Mazda's many outside vendors and the plant in Hiroshima is done indoors, next to the section of the assembly line where the parts are required. Many of the delivery trucks are designed with conveyors on the truck bed for easy loading and unloading. When the truck arrives in the plant, it is jacked up so that its conveyors match those of the assembly line, and the parts roll off without operator assistance. As a further move toward efficiency, the parts are loaded onto the truck in the proper sequence for the day's production schedule.

In Hofu's metal-stamping shop, two five-unit tandem press lines stamp out most of the body panels for the three different models built in the factory. Forklifts and overhead cranes are used remarkably little, thanks to robots and special-purpose transfer devices that carry raw sheet steel and pressed panels automatically. And replacement press dies are kept on specially designed carts so that the used dies can be pushed out of the press as the new ones are pushed in, allowing an entire press line to be refitted in a few minutes.

But the most highly automated section of the Hofu plant is the body assembly shop, where the stamped panels are spot-welded to form a complete body. Almost 90% of the more than 3000 welds needed to construct a car body are performed automatically, although not all by robots. The 130 robots on the line make about 70% of the welds, according to Tetsuso Komatsu, Mazda's managing director for production planning and engineering. The other automatic welds are handled by special-purpose machines designed and built by Mazda's own engineering staff.

But some welds are still considered too complicated for machines to do cost-effectively. "We do not plan to eliminate the remaining manual welding stations," says Komatsu, "because the investment cost would be too high." Other Japanese carmakers appear to have reached a similar conclusion. At Honda, Nissan, and Mitsubishi, about 10% of the welds for white-body (unpainted) assembly are done manually.

A notable exception is Subaru's Yajima plant, about 50 miles north of Tokyo, where virtually all of the welds are done by robots or automatic welding machines. Only three people are required to supervise a welding line that is capable of producing some 24,000 units per month in four body styles with more than 150 possible variations. To identify the variation in each case, the car body has a series of holes in the underframe that can be read by optical sensors; the correct program for the spot-welding operations at each welding station can then be selected. This simple, reliable system was developed by Subaru's own engineers, reports Hiro Sumiya, manager of the manufac-

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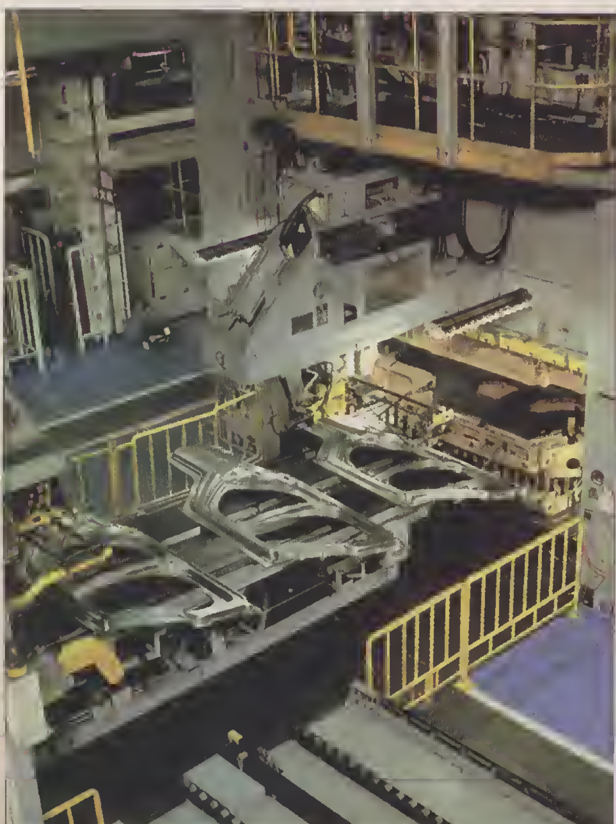
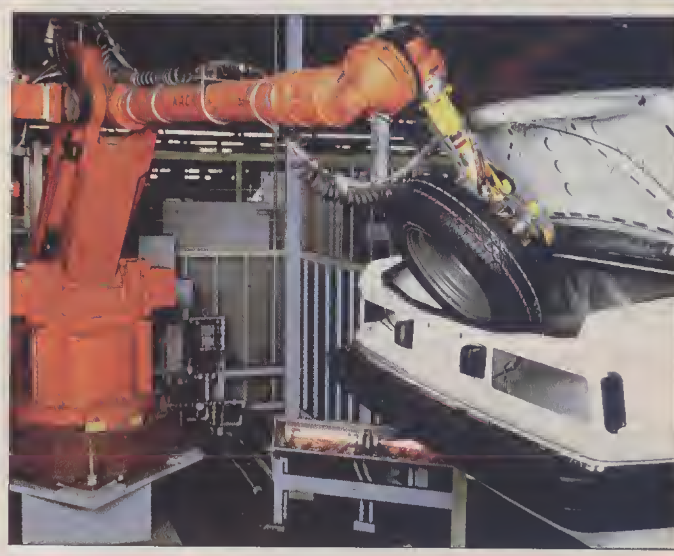




In most Japanese auto plants, such as Mazda's Hiroshima factory (top), car body assembly is almost completely automated with a combination of robots and special-purpose welding machines. Final assembly and trim operations are less automated, although several manufacturers, notably Nissan (above), use robots for relatively simple but arduous tasks like installing batteries and spare tires. Japanese production engineers are also concerned with simplifying and speeding material handling, as in the transfer press line at Honda's Saitami plant (left).

turing engineering department. "We were one of the first carmakers to use robots," he claims. And having reached about 90% automation for white-body assembly, says Sumiya, "we wanted to further challenge our engineers with the goal of 100%."

Body painting is another operation that is well suited to automation; moreover, higher quality is obtained, and workers are relieved of an unpleasant task in an unhealthy environment. At Mazda's Hofu plant, the dipping and painting process is fully automated. Final coats are applied by automatic stationary paint sprayers that coat the major body parts and by a variety of robots that paint hard-to-reach places. Gaps between components of the underbody are sealed by robots with optical sensors that determine when each one has been filled. The paint shop is pressurized to keep out dust and contaminated air, and water flows continuously under the steel mesh floor to trap falling dust and paint particles.

Much of the automated machinery for Honda's mixed-model car plants, such as the robots shown on the Accord line at the company's Saitama plant, is designed and built by a subsidiary, Honda Engineering Company.

Paint quality is virtually an obsession with Mazda and other Japanese carmakers. After drying, the bodies are subjected to a rigorous and lengthy inspection. At most Japanese plants, this job is done by teams of inspectors trained to spot minute defects. But Nissan, in an attempt to reduce the time and personnel required for this difficult task, has recently installed laser-equipped scanning robots at its Murayama and Oppama plants, near Tokyo. A pair of robots can scan the entire painted surface of a car in a little over a minute and detect irregularities as small as a hundredth of an inch, according to Itaru Koeda, deputy general manager of Nissan's production engineering department. A similar manual inspection would take at least 45 minutes, he claims. "We think our robots can detect at least 90% of the defects that would be spotted by our best inspectors," says Koeda, but he adds that some visual inspection is still necessary to meet Nissan's standards.

Nissan has been the leader in applying robots to vehicle manufacture, with almost 2000 in operation at the company's 10 car and truck plants in Japan. At the Zama plant, about 20 miles southwest of Tokyo, Nissan has been developing robots for the final-assembly line for the Sentra series (called Sunny in Japan). Originally a truck plant, Zama has been rebuilt several times as Nissan struggled to keep pace with the rapidly rising demand for its cars. In 1984, one of the plant's two final assembly lines was modified to allow Nissan's production engineers to explore the use of robots. Today some 15 robots and 10 specially built automatic machines handle such tasks as installing the battery, window glass, and seats; filling the radiator and screenwasher; fitting the rear doors, rear lamps, and spare tire; adjusting headlight aim; and measuring wheel alignment. These machines do the labor of about 30 workers, sparing humans a lot of heavy lifting.

Installation of the robots was not without a few major problems, generally caused by the existing production line. For example, a conventional final-assembly line is a continuously moving conveyor, often with wide slats that carry workers along as they complete their tasks. But if such a conveyor were outfitted with large industrial robots, which need to be fixed in place, the entire line of cars would have to be stopped for each assembly operation. Instead, Nissan developed a shuttle system in which car carriers can be stopped individually, allowing the robots to perform their tasks before the car rejoins the moving line.

Another problem is that robot arms often need more room than human workers. For robots to install seats, the doors must be removed and then reattached, a step not usually necessary with a manual assembly line. However, says Toshiya Yamamoto, a Zama plant manager, "we found that other operations are made easier with the doors off, so they are now detached at the start of the assembly line and replaced near the end, giving both robots and workers much easier access to the car's interior."

Still, only about 8% of the operations on the final assembly line are automated, reports Koeda. "We intend to pursue further automation, but we may have progressed about as far as we can with current car models, which are designed for conventional assembly lines. In the future, when we design cars for automated assembly, we might be able to automate as much as 50% of final assembly operations." (In this respect, Japan may be lagging the Europeans. Volkswagen's latest plant, in Wolfsburg, West Germany, reportedly has automated more than 30% of the final assembly line, but largely with special-purpose machines rather than industrial robots).

Most Japanese automobile executives feel that further automation is an absolute necessity. "In Japan we have no 'guest workers,'" says Koeda. "As living standards improve and levels of education increase, assembly line work will become less desirable." Consequently the sources of cheap labor are limited and steadily drying up. Commercial considerations are a powerful motivator, too. "We make almost 200 types of vehicles today," says Jitsuya Asano, administrative manager of Honda's Sayama plant. "If you count options, that's about 5000 possible variations. As car buyers become more sophisticated and the market gets more competitive, we'll have to respond with even more variations." □

PACKING MORE PUNCH

HAMAMATSU—In the two decades since 1960, Japan's Big Four motorcycle makers—Honda, Yamaha, Suzuki, and Kawasaki—have come to dominate the world market with models ranging from tiny mopeds to huge touring bikes. "We succeeded because we could produce motorcycles efficiently and economically," says Kazumi Hamazaki, a Honda motorcycle sales executive. "But times have changed and competition is stiffer. We now have to be the innovators, achieving design superiority as well as production superiority." In addition, Japanese manufacturers are pursuing markets for "power products" such as lawn mowers and outboard motors, using the design and production experience gained with motorcycles.

Japanese innovation can clearly be seen in the power boosting of the tiny 50-cc engines that drive about 80% of the 2 million motorcycles sold in Japan. Ten or fifteen years ago, notes Hamazaki, those engines struggled to produce a little more than one horsepower. "Today we have production 50-cc engines that develop almost three horsepower, and we expect to go to 4.5 horsepower shortly." Most of these gains have come from increases in compression ratio and reduction of frictional losses in the engine itself, according to Honda engineers.

Similar efforts have been devoted to improving the performance of larger motorcycle engines. For example, "in 1978, our 1100-cc engine developed about 100 horsepower, very good performance at that time," says Kazuo Aoi, a Yamaha staff engineer responsible for engine design. "Now we can produce the same horsepower in a smaller 750-cc engine that weighs 30% less.

In their search for higher performance, Aoi and his design engineers first took note of recent developments in multivalve car engines. "We went one step further than the car engine guys with their four-valve-per-cylinder designs," says Aoi. "We went for five valves per cylinder—three intake and two exhaust." In fact, with typical Japanese thoroughness, Aoi and his colleagues investigated engines with four, five, six, and even seven valves, building and testing several models before concluding that five valves would be optimum. Aoi's design is now available in the U.S. on a bike with a four-cylinder, 697-cc engine that outperforms many larger engines.

All the Japanese motorcycle makers are racing to offer the most power for the least weight. "I think we can reach 200 horsepower per liter in a production engine—we're already approaching 150 today," says Etsuo Yokouchi, Suzuki's chief engineer. Of course, it's unlikely that many consumers will want to ride a 200-horsepower motorcycle, but the power enhancements envisioned by Yokouchi could mean that a 400-cc engine of the near future will have the performance of today's conventional 750-cc engine. Indeed, Suzuki's latest "concept" motorcycle, powered by a newly designed square-four, 400cc, 13,000-rpm, four-stroke engine, is said to rival today's 750-cc machines.

In Suzuki's latest oil-cooled, four-cylinder, 1100-cc engine, a high-capacity cooling pump delivers 20 liters of oil per minute to eight cylinder head jets, and similar high-pressure

Suzuki's experimental motorcycle, the FalcoRustyco, has a high-power, lightweight 400-cc engine with a shift-free hydraulic transmission.

by Jeffrey Bairstow

Honda's HR173 lawnmower is powered by a 2.4-horsepower four-stroke engine with transistorized ignition and automatic decompression for easier starting.

jets spray the inside of the piston heads. The engine runs 30–40° C cooler than conventional air-cooled systems and is 22% lighter, claims Yokouchi. He should know: a year ago, Yokouchi and his chief assistant, Munenori Kiryu, took a pair of bikes for a 5000-mile test trip across the U.S. "No serious problems," he reports, "but we have redesigned the seats for more long-distance comfort."

With these and other design innovations, Japan continues to lead the world motorcycle market, despite a drop in production from a high of 7.4 million in 1981 to only 4.5 million last year. Partly in response to that drop, the Big Four motorcycle makers are diversifying into generators, outboard motors, snowmobiles, lawn mowers, and other small-motor applications. "We've already reached a 50-50 ratio between motorcycle sales and other power products," says Toshimori Shuin, Yamaha's managing director. "And we expect to improve significantly on that in the next few years."

Yamaha's archrival in the motorcycle business, Honda, has long been the major Japanese producer of power products. In 1985, Honda made more than 1.3 million such small engines, over 80% of which were exported. "There's not much of a domestic market for products like lawn mowers, garden tractors, and snowmobiles," says Shinya Inoue, marketing manager for Honda's overseas power products division. Indeed, Honda has had a plant in North Carolina assembling lawn mowers since 1984 for its rapidly growing North American market.

Suzuki has also diversified into power products. In particular, the company has become a major supplier of outboard motors, ranging from a 2-horsepower, 50-cc unit to a 200-horsepower V-6 that has a 2.7-liter displacement (larger than most Japanese car engines). Suzuki also supplies lawn mower engines to the Toro Company in the U.S., competing with Briggs & Stratton (Wauwatosa, Wis.), long the dominant supplier of such engines in North America. Similarly, Kawasaki is building mower and garden tractor engines for John Deere.

But while Briggs & Stratton seems content to remain a supplier of engines to companies such as Toro, Snapper, and Homelite, the Japanese makers, particularly Honda, prefer to sell their own manufactured equipment in the consumer marketplace, where the risks are higher but the potential for long-term profit is considerable. Thus Honda is already the leading supplier of small portable gas-engined generators in the U.S. and is making a very determined effort to capture a large slice of the higher-priced lawn mower market; both Honda and Suzuki are making considerable gains in the small outboard motor field at the expense of U.S. manufacturers Mercury and Outboard Marine Corp. (maker of Johnson and Evinrude motors); Yamaha is already a leading supplier of gas-engined golf carts and is making snowmobiles.

Just as innovations in racing and concept motorcycles have filtered through into production bikes, improvements in engine technology that are already accepted in motorcycle engines are beginning to appear in other power products. For example, motorcycle engines use overhead valves for greater power and better combustion efficiency. Until recently, most small engines for lawn mowers, pumps, and generators were older side-valve designs, which are simple to engineer and cheap to manufacture. These models are often more compact than a comparable overhead-valve engine, an important factor for small gasoline-powered devices, but they develop less power. In early 1984, after several years of development, Honda introduced a series of small overhead-valve engines (up to 11 horsepower). Honda has since been followed by the other Japanese power product makers.

Generally, overhead-valve engines are more powerful because they have a much higher compression ratio (8:1, versus 6:1 or less for a side-valve engine). However, the higher compression makes the engine harder to start. While this is not a serious problem for electric-start engines, most small power products use a recoil starter that is pulled by hand. Thus the engine compression must be lowered for easier starting. To this end, Honda's engineers devised an ingenious automatic decompression system that prevents the valve from closing completely during starting, thus reducing the engine compression. As the engine gathers speed, the decompression plate is shifted by centrifugal force to allow the exhaust valve to close completely. The engine then runs with its normal high compression.

Although they have been building outboard motors for some 20 years, it is only recently that the Big Four have begun to pose a serious threat to the major U.S. manufacturers. They have done this largely by introducing features that make motors easier to operate and more reliable. Suzuki, for example, was the first to manufacture oil-injected outboards, thus simplifying the problem of ensuring the correct mixture of oil and gasoline for a two-stroke engine. Suzuki uses a mechanical pump to spray oil directly into the fuel intake manifold; the pump responds to changes in engine load and revolutions, automatically varying the fuel-to-oil ratio from 150:1 at low speeds to 50:1 at full throttle. Meanwhile, Honda, drawing on its long experience with small four-stroke power products, is developing a line of four-stroke outboards that do not require any mixing of oil and fuel.

Although such improvements in engine design and performance are impressive, Japanese engineers see them as merely steps along a lengthy and difficult path. "The gasoline engine has a 100-year history," says Yamaha's Shuin, "but in my view it has not reached technical maturity and has a long way to go." Shuin expects his engineers to push harder toward that goal—as do his counterparts among the other Japanese manufacturers—in the race to develop better performance and expand market share. □

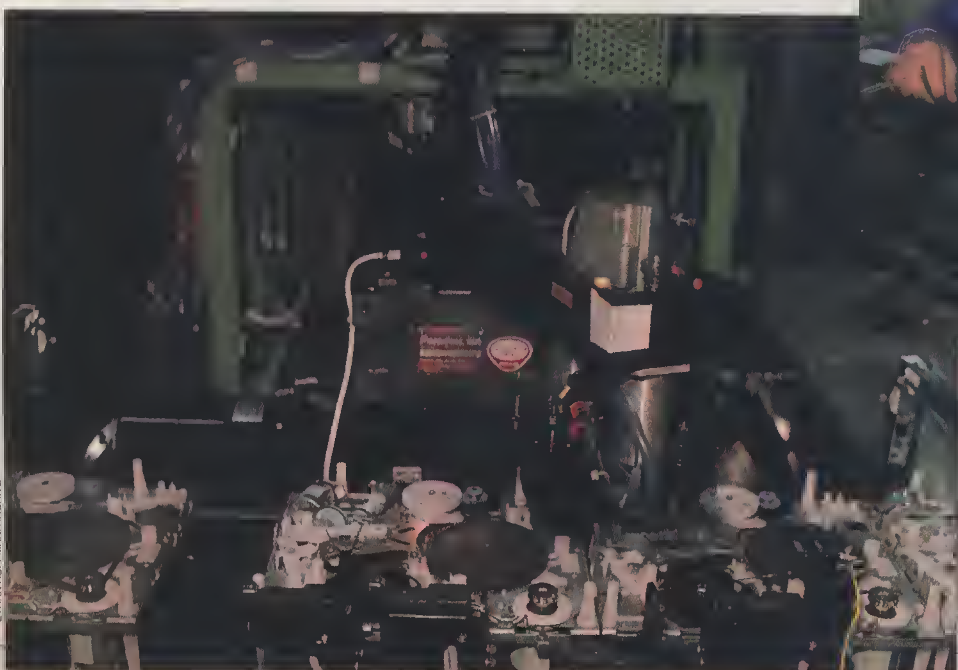
WHERE PEOPLE HAVE A PLACE—FOR NOW

OKAYAMA—Considering that their goods practically define high technology for many people, Japan's electronic-products manufacturers have been surprisingly slow to automate their factories. For example, the Epson dot matrix printers, which captured a large chunk of the low-end market, have been built on largely manual lines. So have Sony's highly regarded 3.5-inch floppy disk drives, used in Apple and other computers.

One reason manual production remains attractive to Japanese manufacturers is the fairly low cost of labor. Assembly workers at a Matsushita VCR plant in Okayama earn an average of 2 million yen ($12,000) per year, according to general manager Masao Nakata. The average age of all workers at the plant, including the 30% in administration and engineering, is 26. At NEC's Ibaraki factory, which makes small business computers and hard disk drives, the average age of the assembly workers is only 22, and most of them are women. Indeed, electronics production in Japan relies heavily on young female

by Robert Poe

ETHAN HOFFMAN/ARCHIVE



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Machines are only slowly replacing the young female workers who have dominated electronics assembly in Japan. At left, rubber drive belts are automatically installed in VCRs at Hitachi's Tokai Works—a job still done manually on another line at the same plant (above).

assembly workers. Conscientious and dextrous, they start work directly after high school, and generally continue only until marriage in their early or mid-20s; with such brief careers, salaries tend not to rise much above starting levels.

Another factor staving off automation is the need to maintain an ultraclean environment. Electric motors and moving joints generate dust. Some companies have introduced "clean-room robots," with the offending sections sealed. But their high cost—at least double that of conventional robots—has kept the clean room largely a human preserve. NEC and other companies use row upon row of clean-suited workers to put together hard disk drives. But there are plenty of applications in which automation pays, such as high-volume manufacture of identical products. Because production demand outgrew its manual plant, Sony has for almost a year made its floppy disk drives in an automated factory. (Floppy drives tolerate much less pristine environments than hard disk drives, so clean-room robots are not required.)

Machines have virtually taken over the task of stuffing printed circuit boards with microchips and discrete components. The insertion machines are faster than humans and, when connected to sophisticated computer networks, are about as flexible. One production line at Toshiba's Ome computer peripherals factory, for example, can turn out a mix of 1000 boards, each carrying a different combination of components.

NEC uses a rudimentary machine vision system to mount chips for use in small business computers. The chips come in surface-mounting packages with leads separated by a mere 400 microns. It takes a machine's repeatability to assure that these leads will land on the contact pads for subsequent soldering. The vision system locates the pods, then tells the robot where to move and how to turn its hand to make the connection.

Because the assembly of dot matrix printing heads requires positioning as many as 24 pins to an accuracy of 50 microns and bending each to a slightly different angle, it has until recently required the delicate touch of a human hand. But inserting these pins, a four- to six-minute task, has been the most time-consuming step in making the printer. Thus Toshiba has automated the process with a new machine that takes only two minutes to simultaneously load two print heads; the machine has the capacity to handle five heads at once.

Japan's piecemeal approach to automation has worked well in automating high-volume mass production plants. But for future success, a company must be able to bring out new products quickly and with minimal disruption to its production line. Such flexibility is not acheived by automation alone. At the Matsushita Okayama plant, for example, most of the 145 machines on the final-assembly line are dedicated to specific tasks. "When we start making a new-model VCR, our production engineering division has to make new read-only memories for our assembly machines," says general manager Nakata. "And we have to pay them to do it." Another example is Sony's new floppy disk factory. Although the plant uses state-of-the-art robots, changing programs between production runs for different models is still done manually, according to Yoshinori Tanaka, general engineering manager

True flexibility depends not just on programmable robots and machine tools but on the coordination and control of the different machines. In Japan this has traditionally been the province of the workers, who have created elaborate systems to ensure that all the machines receive the right number of parts and turn out the correct number of products. But given the increasing amount of information that needs to be conveyed, Japanese electronics manufacturers may be driven to replace their human networks with sophisticated factorywide data communication systems.

The company that has made the greatest strides in this direction is Toshiba. "Our goal is to be able to manufacture products in lot sizes of one," says Tadashi Kurachi, engineering administration manager of Toshiba's Ome Works. To this end, the company has developed a computerized factory management system that oversees all aspects of manufacturing, from monitoring deliveries of raw materials to controlling robot arms in real time.

The Toshiba network consists of four layers of computers, with commands transmitted from top to bottom. At the printer final-assembly line, for example, a mainframe computer sends out a plan—essentially, how many of what type of printers to make—to a superminicomputer that controls production. When it's time to change printer models, the supermini passes the word down to a minicomputer, which consults its complete library of programs for assembling the different printers. The minicomputer downloads the appropriate set of instructions to microcomputers at various stations on the production line. These micros tell the robots and assembly machines what parts to pick up and where to place them on the printer.

As an aid to automation, Japanese electronics companies design products to be easy to manufacture. In many cases, assembly involves attaching all the parts from the top, avoiding the need for more agile (and expensive) robots. In addition, the overall number of parts is minimized, often by assigning multiple functions to each component. This has led to an increasing use of plastic instead of metal parts; plastic can be molded to more complex shapes that can perform a greater variety of tasks.

There are other ways of saving assembly steps as well. In Sony's disk drive, for example, all electrical components, including the windings, are mounted on a printed circuit board; all mechanical components, including the rotor and bearing, are on an aluminum chassis. Thus the motor is created simply by installing the board on the chassis, without the usual need for prior subassembly.

Manual backup may be needed to keep an assembly line moving when a robot breaks down. At a Matsushita VCR factory, for example, robots operate on one side of the line so that if necessary, a person can take over its job from the other. Diagrams of a chassis or printed circuit board above each of the 146 robot stations indicate the part being inserted, and color indicates the operation (attached, screwed in, etc.). The diagrams provide quick, clear communication.

Hitachi has married the idea of designing for producibility with the Japanese penchant for quantification. Using a system it calls the Assemblability Evaluation Method (AEM), the company scores the product design, with 100 being the easiest—and hence the cheapest—to assemble. A design that scores too low goes back to the drawing board. Guided by AEM, Hitachi set about redesigning the tape-moving mechanism of its VCR. One result was a reduction in the number of parts from 460 to 379. This was attained by such simple means as machining the tape guide in one piece; previously it had consisted of a short bar attached to two end caps. The company also replaced tangle-prone lead wires with rigid connectors, substituted a thicker washer for a thin one that tended to cause difficulties for the assembly machinery, raised a right-angle lip on the base of

the motor assembly to stabilize its position in a rectangular chassis, and rounded the tips of screws for easier insertion. All told, the changes raised the AEM score from 63 to 73.

Most Japanese companies state that they don't hesitate to install automation wherever it makes economic sense. "Our rule of thumb," says Ryuichi Nakamura, general manager of Seiko/Epson's floppy disk drive department, "is that we will use a machine instead of a worker if it can pay for itself within two years." With robots and single-task assembly machines costing as little as 4 million yen ($24,000), the substitution is often economical if one machine displaces one worker.

But in some cases a person's job consists of more than one step; automation would thus require the expense of more than one machine, and the human worker could prove more cost-effective. At Toshiba's

Right: A few feet away from a robotic assembly line, electronic typewriters undergo manual testing at Brother's plant in Nagoya. Below: At Toshiba's Ome Works, a tightly woven computer network bestows production flexibility. The chip insertion line can turn out a mix of 1000 printed circuit boards, each carrying a different combination of components.

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printer factory, for example, the main assembly line will be fully automated by year's end—except for one manual station, where a worker attaches a retainer that helps hold the roller in the correct position, meanwhile pushing another part of the printer mechanism out of the way. Since it would take several robots to accomplish the same task, this operation will be done manually for some time to come. □

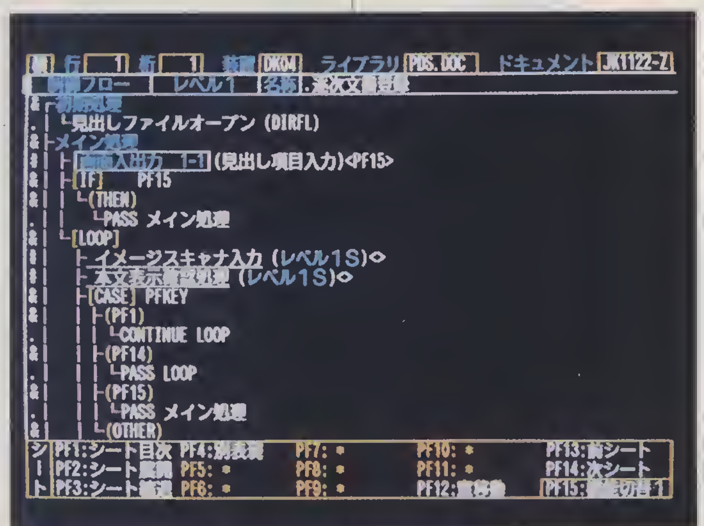
Robert Poe, who lives in Tokyo, reports regularly on Japanese technology.

SOFTWARE

TOOLS FOR COMPATIBILITY

ONE—Japan's greatest weakness in computers has been software. But efforts are now being focused on overcoming that weakness, and on building a strong competitive edge for Japan's computer industry in the process. A major national program and many individual company projects aim to improve software quality and productivity by developing techniques that range from reusing parts of previous programs to fully automating software production.

The heart of Japan's software push is the national Sigma project, a 5-year effort begun in October 1985. Funding will include $150 million from the government plus almost as much from participating Japanese firms. Headquartered at the edge of Tokyo's Akihabara electronics district, the project is directed by the government's Information-technology Promotion Agency (IPA). The Sigma team hopes to do what no other nation has done: achieve absolute compatibility, so that any Japanese software can run interchangeably on any Japanese computer.



Programmers will be able to use special software development workstations linked together (and to Sigma headquarters) over a national wideband network. Powerful programming tools will be offered to encourage use of the workstations. Planners estimate the network will link over 10,000 software development workstations by 1990. They hope an extensive software library will take shape, with both software listings and actual programs accessible over the network, either gratis (for some IPA offerings) or for sale commercially.

Compatibility will center on a standard operating system (OS) to be based on an advanced version of Unix, originally developed at Bell Labs in the U.S. (see "How national software efforts stack up," p. 36).

All the Japanese mainframe computer manufacturers and several other electronics firms are in the program, including NEC, Fujitsu, Hitachi, Toshiba, Oki, Mitsubishi, Sharp, Sanyo, Omron, Ricoh, and Sumitomo Electric. These companies send engineers and work cooperatively with Sigma headquarters in developing software operating environments. "We hope all these manufacturers will also build the workstations," says Youichi Ishikawa, deputy director of the Sigma project.

by Robert Haavind

The software development workstation would cost about 3 million yen ($18,000) a year from now, falling to 1 million yen (about $5900) by the end of the project in 1990, estimate Sigma planners. Only the interface definition for the workstation will be specified, so that manufacturers will be free to compete on performance. The machines will be as powerful as a MicroVAX (a Digital Equipment Corp. VAX computer built with advanced microchip technology), but are intended to be an improvement on this machine. They will have a 32-bit central processing unit that can handle over 1 million instructions per second (MIPS), a floating-point processor, at least 4 megabytes of main memory, and a bit-mapped graphics display of at least 1000 × 1000 dots resolution capable of displaying at least four independent windows. Color will be optional.

Other peripherals will include a hard disk drive of at least 80 megabytes capacity, a streaming tape with 40 megabytes capacity, 5-inch floppy disks that will hold 1.6 megabytes, and a laser printer with at least 300 dots/inch resolution that can print 10 or more pages a minute. The keyboard will be an improved version of the Japanese Industrial Standard. The system will allow syllables typed in roman characters to be automatically translated into

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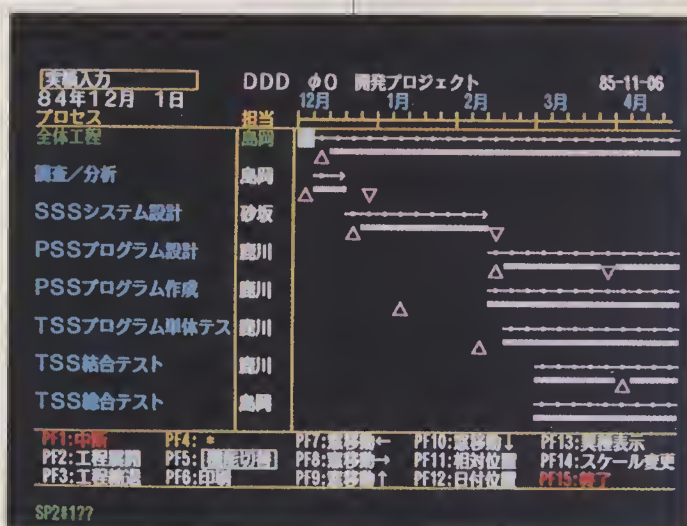
kana characters. It will have some understanding of context, but so far no artificial intelligence techniques are planned.



Tools developed by Toshiba's Ome Works to aid programmers in reusing parts from existing software are examined (above) by Takeo Funatsu, assistant factory manager, and Yasuo Suzuki, office automation equipment manager. Program part's structural description is color-coded (opposite page). Blue sections are never changed; white sections must be revised for each application; and yellow sections usually remain the same. The system also provides project management capabilities, such as time and cost estimates (left).

Workstations will be supplied with some basic tools for software development, including editors, documentation aids, and Japanese language processors. Project management tools would be offered as an option. Also, each user will need some special tools—for process control, business data processing, or other specific application areas—that would be ordered from the Sigma Center in Tokyo. Each user site, whether a bank, factory, or software company, will be permitted to devise its own software development environment, optimizing the combination of tools. Performance of the Sigma installation could be upgraded, but to ensure absolute compatibility within the network, no changes to user interface functions will be permitted. A local-area network (LAN) based on Ethernet is also planned.

Network users will be supplied with several services, including electronic mail, a bulletin board, an electronic newsletter, file transmission, trial use of Sigma tools, access to domestic and overseas networks and databases, and access to a wide range of data processors for testing software under development. Some of these machines may not use the Sigma OS, but gateways will enable programmers to use them conveniently. These target machines may be supplied by service bureaus that charge for their use.

Software development tools such as in-circuit emulators, PROM (programmable read-only memory) writers, and software assemblers are planned for a wide range of micropro-

How national software efforts stack up

"Sigma is better organized than any other national effort, involving more cooperation between hardware and software developers, the government, and computer users," says Kyozaburo Mawatari, a Sharp engineer who works with the Sigma group.

Its great strength, according to Mawatari, is that Sigma will support all levels of software development, from cottage industries to projects involving hundreds of programmers, such as on-line systems for large banks. Sigma's network will permit software writers to see what others have done and to improve on previous work.

Other nations may have programs involving more advanced software, but they are research-based while the Sigma project is for practical application, emphasizes planning manager Noboru Akima. He acknowledges that choosing Unix and the C language to produce primarily Fortran and Cobol programs means that Japan's project won't be at the leading edge of software research; universities in the United States are significantly more advanced in this area. But he points out that it takes about 10 years for advances at U.S. universities to enter the commercial marketplace.

Developing a standard operating system, even based on available technology, will be a major project for Japan. Since they are shooting at a moving target, the Sigma team will use the most advanced versions of Unix they can obtain. Because most Japanese computer vendors favor AT&T's Unix V, this will be the basis for Sigma's OS. But important features offered by a version of Unix from the University of California at Berkeley will also be included. In June, AT&T introduced an advanced version of Unix with a remote file server and more powerful virtual memory management, and Berkeley 4.3 will soon supplant the current 4.2.

Most of Sigma's Unix will be written in the C language, but some will be in Sigma's own assembler language. Software workstations will use the Sigma OS, but computer makers who opt to use their own operating systems will have to produce interfaces to it.

The Japanese understand that a more academic approach, based on formal specification languages that are better defined mathematically, might prove more suitable for the automatic generation of computer code. But since Sigma is oriented toward practical use rather than research, it won't support such an approach. Instead, a joint system development group, also run by the IPA, recently began a study of this possibility. Akima says this would be closer to Britain's Alvey project at the University of Manchester, which is also concentrating on software development tools.

In the United States, software engineering efforts are largely uncoordinated. MCC (Microelectronics and Computer Technology Corp.), a research cooperative set up by a group of computer companies in Austin, Tex., is working on software engineering. Their projects are not at the operating system level, although some interchangeability may result. The Defense Department's Ada software program (HIGH TECHNOLOGY, Feb. 1983, p. 49), aimed at improving software quality, productivity, and reusability for military systems, is closer to what the Japanese are planning. It was a big stimulus to them even though its scope is limited to coordinating military software activity and even though it is taking a long time not only to get Ada tools into the marketplace but to overcome interservice rivalries that have dampened past compatibility efforts.

Other software engineering programs are being conducted by Esprit, the European Community's joint technology program headquartered in Brussels, and by the West German government, which is also sponsoring an Ada project.

cessors, from 4-bit to 32-bit types. An assembler language is also being developed, especially for use with the smaller microprocessors, according to Kyozaburo Mawatari, a software engineer from Sharp who works with the Sigma group. The language is based on C, the AT&T language used to write the Unix operating system.

So far, according to deputy director Ishikawa, there has been support for Sigma plans throughout Japan's computer industry. But there is concern among software companies about protecting their intellectual property rights. This will be one of Sigma's biggest problems. Mechanisms will be needed to pay for software, including the cost of developing the operating system. Fees and licensing policies are now being considered.

Although the Sigma workstations are conceived as special-purpose software development machines, some Japanese manufacturers may also choose to market them as powerful supermicrocomputers. They would have a strong appeal to customers in the Japanese market because they would use the standard Sigma OS, so they could run all Japanese software directly. This might give these vendors a strong competitive position versus IBM, suggests Mawatari. A major reason for IBM's strong microcomputer sales is that so much software is written to be compatible with its de facto standards.

In addition to the coordinated national effort, many Japanese companies also have extensive software improvement programs. Because it is common in Japan to reuse parts of previous programs, tools are being developed to enable programmers to easily find applicable sections of code and modify them for new applications.

Progress is also being made on automating programming, for the most part within limited application areas. Automating system software production is more controversial. Because considerable creative input is needed from the programmer, "system software production can't be automated," maintains Kazuhiko Nishi, executive vice-president of ASCII Corp. (Tokyo), who directed work on the standard MSX operating system for Japan's consumer microcomputers. Nevertheless, system software tools are under development at some companies.

Discipline and adherence to rigid software engineering practices are common in Japan, making the climate for automated programming more favorable than it might be in a more freewheeling setting. Software is often developed in regimented, factorylike settings different from anything in the United States. When asked if Japanese software houses suffer from the same personality quirks complained about so often in the U.S., Tetsuya Mizoguchi, general manager of engineering for Toshiba's Ome Works, seemed puzzled. He says he knows of no such problems in Japan's software industry.

The leader in application software productivity is probably Toshiba's Software WorkBench factory in Fuchu, which specializes in process control programs for industry. About 2000 programmers write code and debug programs

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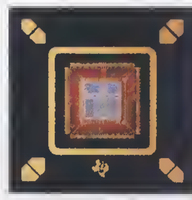

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▸ *See back page for more information.*

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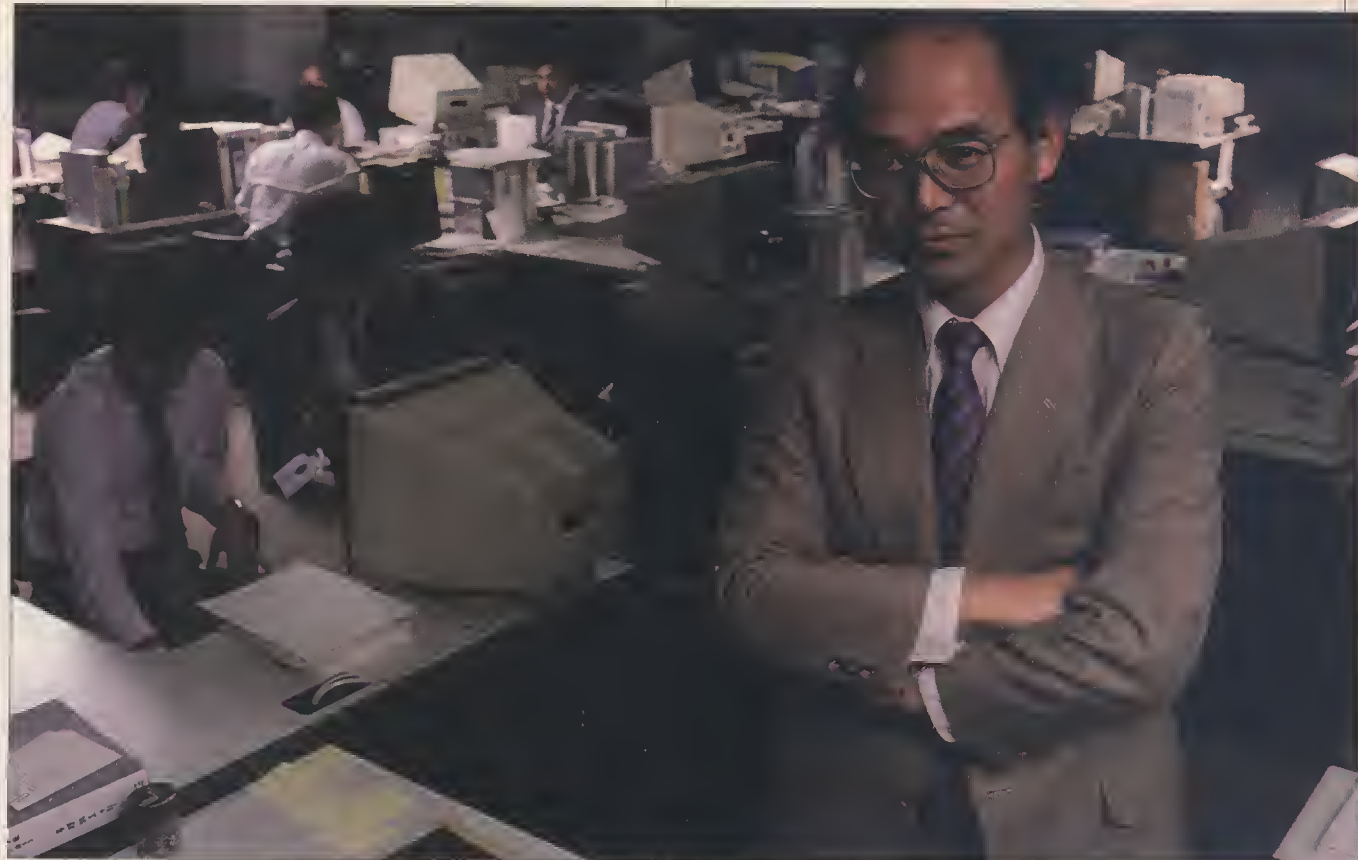
TEXAS INSTRUMENTS



LOU JONES

Japan hopes to achieve national software compatibility, and to devise standard software development workstations that will be manufactured by several companies and linked to a network managed from Sigma project headquarters (above). Planning manager Noburu Akima foresees 10,000 workstations on the network by 1990. NEC has been a leader in software engineering (right) and is now developing a variety of software systems for automatically generating program code.

at workstations, all in one large room. Because this software is concentrated in a well-defined domain, many program parts can be reused—an average of about 65% of the code comes from previous programs. This heavy reuse helps each programmer put out some 2000 lines of code per month, several times the productivity rates in the United States. It also contributes to the software's quality, reported to be very high. Toshiba claims error rates of about 0.3 bug per 1000 lines of code, so good that the company offers a 10-year warranty (any bug found within 10 years is fixed free of charge).

Methods of reusing parts of programs for a much wider

application range are being developed at Toshiba's Ome Works. Programmers can put in and retrieve parts from previously written and tested programs that can then serve as a chassis for new programs. To make retrieval easier, the software directory has three levels: personal use, project use, or the entire file. Parts are given descriptive labels by the programmer who wrote them, so that a software engineer can tell which ones might be applicable to a new program. A new system is being planned that will retrieve parts by functional definitions, making it easier for the software writer to find applicable ones, says Mizoguchi. Program parts that perform generic functions are saved, while more specialized portions are discarded.

Once the system has located a suitable program part, it displays clear, color-coded structural descriptions on a graphics screen. Basic portions of the program that can't be changed are shown in blue. Portions in white identify parameters that must be redefined for each new application. A programmer can select a white section, bring the existing code onto the screen, and then make needed changes. Yellow identifies parts that can be changed but that usually don't vary from program to program. Most of the parts that are reused are subroutines, such as for geometric transformations in graphics programs, according to Yasuo Suzuki, manager of the Office Automation Equipment Dept. at Ome. Up to 90% of a new program may be built from reused parts, particularly for image processing applications, he says.

The Japanese company that is probably most advanced in software engineering is Nippon Electric Corp. (NEC), headquartered in Tokyo. Three systems under development are called PGEN (for "Program Generator"), Software Development and Maintenance System (SDMS), and SEA/1 (for "Software Engineering Architecture 1"). All three are still under development, although the latter two are already in use. SDMS is used by about 10 NEC divisions, and SEA/1 is handled by 150 dealers.

PGEN, the most advanced system, basically tries to generate source code by understanding the meaning and context of the detailed specifications that a systems analyst would prepare for a programmer. Similar to software for automatic language translation, the system is based on natural-language understanding and knowledge engineering from artificial intelligence technology. It deals with detailed semantic analysis, heuristics (essentially rules of thumb) for understanding dependence relationships, and multiplicities of meanings. If a sentence in the program specifications is missing a word, PGEN tries to fill it in. Work on PGEN is being coordinated with ICOT (Tokyo)—the organization in charge of Japan's fifth-generation computer project, which is developing artificial intelligence technology.

Many Japanese companies are working on such automated code generators, but NEC's PGEN is the farthest along. A completed prototype generates Cobol programs for business use. Debugging will still be needed, because even if PGEN works perfectly the detailed specifications may not be correct.

The basic technology to generate code automatically, which NEC says it has developed, isn't enough. There are many application domains, and each requires its own dictionaries and knowledge bases. There are words with special meanings in banking, for example, and to understand context the system must deal with a great variety of banking practices. NEC is developing these, as well as a more complete dictionary of verbs. Also, says Kanji Iwamoto, engineering manager for the software engineering department, "we need a program function for the semantic analysis of verbs." And although Cobol is useful for general-purpose software, some programs may require other languages to handle a specific problem domain.

Right now PGEN works only with detailed specifications that are already very close to source code. Within two years, Iwamoto hopes the system will be able to go all the way from software requirements to program code. The system would also be much more powerful if it could be extended to work with parts of programs, such as common subroutines, and automatically adapt them to a new application, rather than simply doing line-by-line coding.

PGEN will first be used by other NEC divisions, and then, if it is successful, sold commercially.

While PGEN is aimed at automating program writing, SEA/1 and SDMS are more like CAD/CAM (computer-aided design and manufacturing) for the software engineer. It is hard to automate system software development, but according to Shuji Nakata, supervisor of NEC's software engineering dept., standardization is far enough along in process control that SDMS can automatically produce program parts in some limited areas. It helps the programmer divide a program into modules, and the hierarchical structure of the program can be defined in terms of a graphic diagram. SDMS checks the validity of the structure and converts it into a design language description. This can be used to produce source code once details such as parameters and functional descriptions of modules are added. It's not yet clear how much SDMS will improve productivity.

There is much more experience with SEA/1, which boosts productivity two- to tenfold, according to NEC. The programmer defines parts needed in a new program, and tries to make use of previously written parts. Resources available from previous development projects include system and program structures, tested programs, an integrated set of program parts, and form and record layouts. Prototyping is possible with SEA/1, so that the programmer can check a planned interface to the user even before most of the code is done. Some portions of a program can be generated from archived program parts, and SEA/1 also provides facilities for testing programs and producing documentation. Each application of SEA/1 also adds useful information to its archives. NEC has a system for evaluating software quality, which considers a combination of reliability, maintainability, and ease of documentation, and programs developed with SEA/1 score about 10 times better than newly written code, says Nakata.

Although Japanese companies are making important progess in boosting programmer productivity while turning out essentially bug-free software, NEC's Nagano is puzzled that he hears about so little similar activity in the United States. The U.S. may retain some mystique from the early days of computers when software grew up as a black art, whereas Japan, which only recently recognized that software is the key to expanding the future uses of computers, is pushing this technology after great strides have been made in software engineering. The cultural setting also favors a more factorylike approach.

Japan's ability to automate programming and to achieve national software compatibility are more problematical. Just as it has been difficult to fully automate language translation, it is likely that a human programmer will always be needed to check the output and to finish the job. But success in gaining acceptance for a standard operating system and a unified approach to software development over a network of similar machines will certainly simplify the problem. □

"WHAT WE NEED IS A BREAKTHROUGH"

TOKYO—At Fudow Chemicals, director Mayao Satow may hand you a tool holder that the company makes for its line of automated machining centers. Though nearly a foot across and six or eight inches thick, the black, clunky-looking holder is surprisingly lightweight. "These used to be made of carbon steel," says Satow. "Our customers hired ex-baseball pitchers to handle them because those men had such strong arms and wrists. Now, even small women can move them around easily."

The tool holder is a molded piece of reinforced plastic (RP)—more precisely, a phenolic resin that Fudow produces and combines with inexpensive chopped cotton fibers. The result is an exceptionally tough, easily molded, corrosion-proof part that weighs only a sixth as much as its steel predecessors. "We can even make them in different colors," beams Satow.

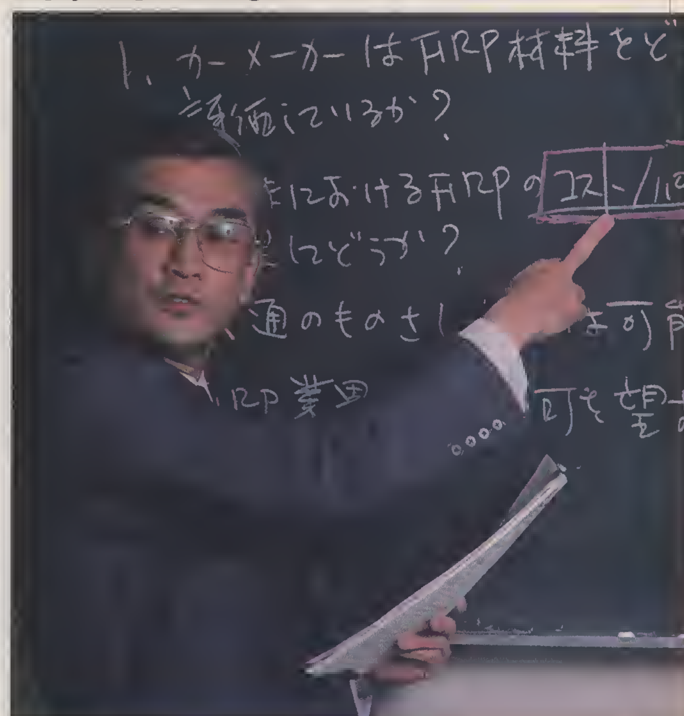
Admittedly not the most exotic example of RPs, the tool holder—like the host of other RP components that go into Fudow's machining centers—illustrates how researchers are out to change the popular image of plastic resin–based systems. Acknowledging that "plastic" is still widely regarded as synonymous with "substandard," designers are serving up a virtual smorgasbord of new products, aimed at demonstrating plastics' toughness and durability.

RP is the general term for systems that combine a lightweight, noncorroding resin with fibers, either woven or chopped into tiny fragments; the most common example is fiberglass, a relatively inexpensive system consisting of polyester resin reinforced with one or more layers of thin glassy fibers. Higher-performance RPs, known as composites, are usually based on such tough, durable resins as epoxies or phenolics reinforced with fibers of carbon, silicon nitride, or various organic compounds in a specific geometric arrangement within the resin.

Since their introduction in Japan in the 1950s, RPs have become one of the nation's most important technologies. For example, fiberglass consumption climbed from a mere 16,000 tons in 1965 to 189,000 tons by 1973, according to Tatsundo Kitamura, research and analysis manager at the Japan Reinforced Plastics Society (JRPS) in Tokyo. The world oil crises plunged the figure to 124,000 tons by the late 1970s, but industrial interest is again clearly on the rise: fiberglass shipments are expected to approach 300,000 tons this year, mostly for such familiar applications as molded bath and laundry fixtures, industrial water tanks, machine housings, and sporting goods. Overall RP growth in Japan is estimated at about 10% a year.

Somewhat surprisingly, Japan exhibits only a limited interest in integrating RPs with its booming auto industry. "The U.S. is much more experienced in this area," says director Kiyoshi Tabei of Tokyo's Nitto Boseki (Nittobo, for short), a major producer of fiberglass, chemicals, and textiles. "With our mass production techniques and inexpensive steel, there isn't much of an incentive to make major design changes in that industry." But with Toyota and several other producers developing proprietary RP technology, the seeming disregard for automotive RPs is almost certainly temporary. "I think the Japanese are getting ready for some catch-up," says Joseph S. McDermott, president of Composite Services (Demarest, N.J.) and former manager of the Society of the Plastics Industry (New York). "It's logical for them to bring on new RP production

by H. Garrett DeYoung



LOU JONES

Plastics face several obstacles in challenging metals and other design materials, says industry analyst Kitamura—including their image of inferiority.

units as they retire some of their older steel plants."

But few industry sources seriously hope to pit RPs against metal across the board. One reason is that even the highest-performance reinforced resin can't approach metal's resistance to heat and chemicals. Another, of course, is the lingering suspicion about RPs' quality—a suspicion that some observers claim is all too often nurtured by the older, more conservative engineers who head most Japanese design groups. "We tend to impose unnecessarily high standards on certain components," explains Satow. "But there are many cases in which a lightweight reinforced plastic is more than adequate for the same purpose."

The near-term goal, therefore, is to increase RPs' acceptance as a complementary design material that in some cases could be an alternative to metal, wood, porcelain, and other traditional materials. In so doing, plastics engineers must also shatter some of the design and processing barriers that have essentially prohibited RPs from such high-performance applications as aircraft engine components.

Reaching those goals will call for improved fibers, fabrication processes, and RP systems. In just this spirit, Nippon Carbon (Tokyo) is promoting its two-year-old Nicalon silicon carbide fiber as a reinforcing agent for epoxy resin composites and other engineering materials, including aluminum, ceramic, and glass composites. The Nicalon-reinforced epoxy exhibits very high impact resistance, according to senior director Masanori Fujii. And unlike conventional carbon reinforcing fiber (which is an electrical conductor), Nicalon is a semiconductor and hence could prove useful in a variety of electrical applications.

Nicalon is made from three organic silicon-based materials that are subjected to a series of reactions and heat treatments. The finished fiber withstands temperatures of up to 1000° C. When combined with another material (molten aluminum, for example), the fiber reportedly increases the material's strength an average of 60%, while reducing its weight 40%.

But the fiber's very high cost rules it out for all but the most specialized plastic systems, says Fujii. As a result, the company is targeting Nicalon into high-precision specialty composites—reinforced glass and ceramics, for example, which are rendered much lighter and more resistant to shattering. Nicalon-reinforced aluminum is another potential market, perhaps as a lightweight replacement for titanium in some applications. As an example of the latter, Fujii cites Nippon Carbon's program with Rolls Royce to develop aluminum composite aircraft engine components.

As one of Japan's top producers of glass fiber, Nittobo might also play a role in advancing RP technology into new areas. However, says Tabei, "we're not sure we see a lot of big new markets for reinforced plastics. Our emphasis is on improving our present technology rather than inventing new materials or methods." Accordingly, the company is focusing largely on developing glass reinforcing fibers for such traditional RP applications as machine housings, automobile leaf springs, fishing vessels, and structural components for trains, buses, and residential and office buildings. Printed circuit boards are another important fiberglass market, consuming nearly 30 million square feet of glass cloth per month. Each board may contain up to 10 layers of cloth for dimensional stability.

Tabei's disclaimer notwithstanding, Nittobo has taken a leadership position in familiarizing engineers and the public with RPs. For example, the company has recently developed a collapsible wheelchair that weighs only 22 pounds, thanks to a glass–carbon hybrid fiber. Tabei expects another of the company's developments, a conductive nickel-coated glass fiber, to appear in such applications as parabolic antennas for satellite transmission receivers.

Fudow's line of automatic machining equipment, meanwhile, serves a dual purpose for its developers: the tools have not only helped to dispel plastics' inferior image but helped the company cash in on the technology by integrating its positions as both supplier and processor.

A long-time supplier of plastic resins, Fudow developed its own composite process in the mid-1970s; since then, says Satow, the company has sold 5 million plastic machine tool parts, making it one of the top domestic suppliers of machine tool systems. Fudow still supplies other types of fibers, fillers, and resins (such as polyesters and epoxies), and is now developing composites consisting of carbon fibers and phenolic resin for such applications as machine shock absorbers.

But the company's star RP performer, says Satow, is its $15-million-a-year machine tool business—largely because of the simplicity of the process. The company uses all types of inexpensive cotton, including scraps from garment manufacturers; chopped and mixed with the phenolic resin, the fibers form a chemically inert matrix. The tool holders and machine frames are produced at the Tokyo plant and in Nagoya by a high-temperature, high-pressure process called compression molding.

Despite these and other marketing successes, it is RPs' limitations, both real and perceived, that still capture most of the attention. For example, even the most advanced high-performance RPs look—well, like plastic. "It's hard to get the same kind of surface finish as with metals," says JRPS's Kitamura. "But we think new finishing systems will soon solve this problem."

One potential solution, says Composite Services' McDermott, is the process called in-mold coating, which is now being used to produce the all-plastic body of the Pontiac Fiero. In this process, the mold is first coated with a thin layer of specially formulated unreinforced polyester; the RP is then laid into the mold as usual. During the cure cycle, the gas bubbles that usually mar the surface of the RP are absorbed by the polyester.

Another RP problem, says Kitamura, comes in joining plastics to each other and to other materials, including metals. Having ruled out rivets, screws, and bolts because of their weakening effects, suppliers are now trying to develop tough new adhesives that will hold up even under high temperature and harsh chemicals. Also yet lacking are automated systems for joining plastics; composite components are now assembled almost entirely by hand.

There is also the question of what to do with reinforced plastics once they've outlived their usefulness. In contrast to the metals industry, there is no major organized program for recovering and recycling plastics. And because of the widely variable physical and chemical properties of the resins and reinforcements, composites usually cannot be simply melted down for reuse (except for manufacturing products of very low quality).

Overcoming such problems is a tall order for RP proponents, in Japan and around the world. And although most sources are convinced that solutions will ultimately be found, it is less certain that better processing and disposal methods alone can substantially boost the acceptance of plastics by designers, engineers, and the general public. What is needed now is not simply more applications for fiberglass and other established RPs—which, as demonstrated by the Fiero, will probably evolve anyway—but a dramatic and well-publicized substitution of a high-performance metal or ceramic with a similarly high-performance plastic. In other words, says JRPS's Kitamura, "what we really need is a breakthrough." □

IN SEARCH OF A WINNING STRATEGY

TOKYO—Barely five years ago, Japan targeted genetic engineering as one of its most vital new enterprises. Given the nation's enviable record of commercializing new technology, it was widely assumed that Japan would be as successful in biotechnology as in automobiles, computers, and consumer electronics. But in Japan, as in the U.S. and elsewhere, biotechnology is still packed with technical and commercial wild cards; only a few of the dozens of potentially important bioproducts are now manufactured consistently, economically, and in quantities of more than a few grams at a time. Another reason for the industry's shaky commercial status is that virtually all genetically engineered products must eventually pass government muster. But "the government still has not set standards for many of these new products," says Shinzo Kagitomi, a spokesman for Ajinimoto (Tokyo), a leading chemical producer. "It could be years before that happens."

Neither technological nor regulatory problems, however, have dissuaded Japanese researchers from laying some all-important groundwork for the 1990s:

□ Conceding that they trail the U.S. and Western Europe in many areas—monoclonal antibodies and plant genetics, for example—corporate planners aim to catch up through heavy investments in basic research and through a growing number of joint ventures with foreign genetic engineering companies.

□ Whereas most U.S. companies have long since staked out specialized market niches for themselves (such as immune-system modifiers or new agricultural products), their well-heeled Japanese counterparts are still scouting the technology for the most secure bridges between the past and the future—and are thus investigating a wide range of processes and products. As a result, most companies feel equally at home with such diverse programs as new cancer therapies, fish growth hormones, and genetically remodeled fruits and vegetables.

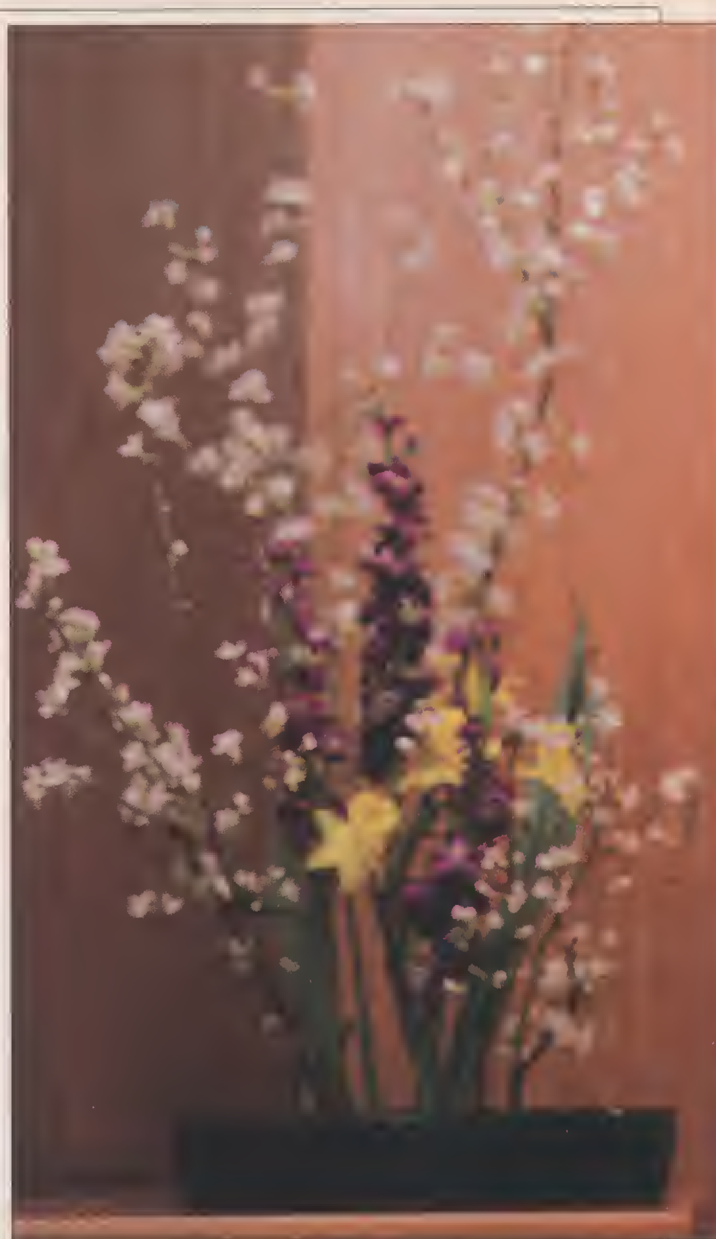
□ Although no genetically engineered products are now being

by H. Garrett DeYoung

A biotechnologist studies new plant varieties at Kirin's research center in Tochigo. Although the company is actively pursuing several genetic engineering projects (including pharmaceuticals), crop genetics will probably play a key role within the next few years: Kirin has already forged a joint venture with a California company to develop genetically uniform "synthetic seeds."

supplied in large volumes, Japanese sources claim that the country enjoys a strong and perhaps deciding edge in production methods. The reason is that while Western biotechnology has been developed mostly by small and relatively independent entrepreneurs, the field has been nurtured in Japan almost exclusively by large, well-established chemical and food-product companies; in fact, the chemical industry makes about 80% of the corporate expenditures in Japanese life sciences research. "That gives us a lot of practical experience in fermentation techniques and in the use of microorganisms," says Yasuki Mori, manager of the Bioindustry Development Center, a key industry trade group based in Tokyo.

Mitsubishi Chemicals, Japan's largest chemical company, is developing products in several areas, but healthcare now gets the biggest piece of the biotech pie, says director Wataru Yamaya; upcoming products include diagnostic antibodies and therapeutics for coronary disease. By and large, however, Yamaya doesn't expect the products to reach the market before the early 1990s—and then only if the company is convinced of a strong marketing advantage.



Consider Tokyo's Kirin Brewery. A leading food and beverage producer for more than a century—and currently the world's fourth largest brewer, with 1985 sales of $4.5 billion—Kirin diversified into life sciences only four years ago. There are now more than 100 genetic engineering researchers at the company's Applied Bioscience Laboratory in Maebashi, working on pharmaceuticals, enzymes, and cell culture. The company maintains another 30 staffers at the Plant Research Center in Tochiga, which serves as a genetic repository for more than 8000 strains of barley; equipment design and production technology research (including new experimental biosensors—essentially hybrids of electronics and proteins—for brewing systems) is conducted at the company's Yokohama technical center.

Through a 50-50 joint venture with Amgen (Thousand Oaks, Cal.), Kirin has developed a new method for producing human erythropoietin (EPO), a hormone that regulates red blood cell production. Keiichi Morimoto, technical information manager at Kirin Brewery, declines to provide any details of the process, except to say that it does not involve bacterial cultures. "This will be the world's first artificially produced human EPO," he says, "but it could be four more years before the government regulations are determined." The company also maintains a joint venture with Plant Genetics (Davis, Cal.) to develop new synthetic seeds—encapsulated, genetically consistent seeds with highly predictable properties and maturation times.

Kyowa Hakko (Tokyo), a top producer of beverage alcohol, amino acids, seasonings, and commodity petrochemicals, is also pursuing biotechnology on several fronts, including immunology-based therapies for cancer (the leading cause of death in Japan). Research programs have recently included two types of interferon, now in clinical trials in Japan, and the immunological regulator called Interleukin-2. Other company research programs are developing the blood-clot therapy called tissue plasminogen activator (TPA), as well as such diverse projects as DNA probes, cancer diagnostics, and genetically engineered salmon growth hormone.

"Not all of these programs will be pursued equally," says Hirotoshi Samejima, Kyowa Hakko's general manager of R&D. "Some may be licensed to other companies, and others could be put on hold. This is still such a young business; it's very hard to predict the future."

Meanwhile, Mitsubishi Chemical Industries, Japan's largest chemical company, has divided its biotechnology research into three major areas (listed in more or less descending order of priority): healthcare, which now accounts for about two-thirds of the company's genetics work; chemical bioconversion; and agricultural products. Pharmaceutical products now being researched include TPA (being developed with Genentech in South San Francisco), diagnostic monoclonal antibodies, and anticholesterol agents. Except for the antibodies, most of the company's new genetics products won't reach the market before 1990 or 1991, says Wataru Yamaya, general manager of life sciences—and then only if they demonstrate some clear advantage over competing products.

Japan's biggest biotechnology attention-getter these days isn't its private corporate programs, however, but an ambitious consortium announced last year: the Protein


ETHAN HOFFMAN/ARCHIVE PICTURES

Engineering Research Institute (PERI), to be based in Osaka. Funded at a total of about $130 million over the next eight years, PERI will develop new methods of producing customized versions of such proteins as enzymes, antibodies, and hormones by combining computer technology with traditional biochemical processing methods. Researchers hope that the program will provide faster and more consistent production of the proteins, which are now manufactured almost exclusively in bacterial or cell cultures.

PERI is the brainchild of five top Japanese chemical process companies—Mitsubishi Chemical, Toray, Kyowa Hakko, Takeda, and Toa Nenryo Kogyo—and the Japan Key Technology Center within the Ministry of International Trade and Industry. The group now consists of more than a dozen Japanese members and at least one outside participant (Britain's Imperial Chemical Industries).

Although some sources claim that biotechnology's acid test will come in the form of process scale-up—the transfer of laboratory procedures to a factory setting—the issue is not yet of great concern to most Japanese planners. In fact, says biotechnology consultant Harvey S. Price in Gaithersburg, Md., scale-up capabilities will not become a significant industrial factor in Japan (or probably anywhere else) until the early or mid-1990s, when genetic engineering will presumably be employed to produce commodity chemicals such as enzymes. "At this point, we need only very small quantities of these drugs for testing and clinical trials," says Kirin's Morimoto.

One reason for the small requirements is that the new drugs show an extraordinarily high degree of biological activity. Just a third of an ounce of pure hepatitis B antigen (the viral protein that arms the immune system) could provide enough vaccine to meet the entire Japanese market, according to Mitsubishi's Yamaya; a source at a top Japanese drug company claims that if the protein called tumor necrosis factor lives up to its early promise, only 25 pounds will suffice to treat every cancer patient in the world.

Most companies are looking ahead, however, and have already set out to solve potential scale-up problems. For example, Kyowa Hakko has developed an experimental culture system that reportedly maintains cells at a density of 10 million per cubic centimeter, about 10 times the density of other systems. Mitsubishi Petrochemical is studying such areas as continuous fermentation technology, while Mitsubishi Heavy Industries—a $12 billion-a-year engineering and manufacturing company—is working on the development of the large new bioreactors that will one day be needed for commercialization.

But it's far from clear whether Japan's formidable economic and intellectual resources will suffice to make it a biotechnology leader. One reason is the openly acknowledged national shortfall in basic research—a limitation that, paradoxically, could be aggravated by the very institution credited with the country's past successes: its system of corporate management. "The industry has made a strong commitment to research," says Kyowa Hakko's Samejima. "But our seniority system often works against what we need most—individual innovation." Nor, adds biotech consultant Price, does industrial fermentation know-how by itself assure successful manipulation of new genetically altered organisms.

Still, there's a powerful sense of mission among Japanese genetic engineers—an optimism unsurpassed in any other nation. And while the national penchant for organization and hard work may not guarantee commercial biotechnology triumphs on every front, it is sure to hold the world's attention for years to come. □

NEC INTRODUCES WORLD'S FASTEST FLOATING-POINT SIGNAL PROCESSOR.

Our μPD77230 Advanced Signal Processor breaks the floating-point barrier in digital signal processing (DSP) with unprecedented speed and accuracy.

The new single-chip CMOS DSP races through 32-bit full floating-point arithmetic at 13.4 MFLOPS. It executes up to 6 concurrent operations, including multiply and accumulate, in a 150ns cycle.

With 32-bit floating-point precision, our advanced signal processor eliminates problems with round-off error, quantization noise, scaling, limit cycles and over/underflow. It is unique in offering a 55-bit multiplier result (8-bit exponent, 47-bit mantissa), with eight 55-bit registers, 47-bit ALU and barrel shifter.

In addition to its large internal memory blocks (512 × 32 × 2 data RAM, 2K × 32 program ROM and 1K × 32 data ROM), the 77230 provides external expansion up to 4K of program RAM and 8K of data RAM. Serial and parallel I/O also add flexibility. The serial interface allows cascading, links with codecs and AD converters while the parallel interface supports master- and slave-mode operations.

The 77230 is ideal for image processing, graphics workstations, telecom and other applications requiring high speed and high precision.

C&C
Computers and Communications

NUMBER 135

NEW ZEALAND GOES DIGITAL WITH NEW FOTS AND NEAX61.

Plans for a nationwide Integrated Digital Network (IDN) in New Zealand, where the telephone ownership rate is among the highest in the world, are rapidly taking shape.

The New Zealand Post Office selected NEC to supply state-of-the-art 140MB fiber optic transmission systems (FOTS) and digital switches that will bring the digital future clearly into view.

NEC will provide all the necessary optical terminal and repeater equipment for the fiber optic systems to be installed in links covering Wellington, Auckland, and other major cities.

NEC's 140MB FOTS provides high-quality communications paths equivalent to 1,920 telephone channels. High-performance optical devices enable long repeater span. It also features in-service system monitoring functions, low power consumption and compact size. A slim rack, measuring 2.75m(H) × 0.12m(W) × 0.225m(D), accommodates three terminal systems.

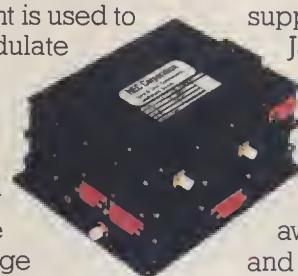
For the development of its ISDN, the New Zealand Post Office selected NEC's enhanced NEAX61 digital switching system with ISDN capability. Nearly 100 systems, including toll and international switches, are to be supplied within a five-year period.

NEAX61 digital switches with an aggregate total of 5 million lines are now in service in 36 countries.

NEC TRANSPONDERS SELECTED FOR INMARSAT-2.

NEC satellite transponders will play a key role in INMARSAT-2, the second generation of international maritime communications satellites.

NEC was recently awarded a contract from British Aerospace Public Limited Company to supply TT&C C-band transponders. This technology-intensive equipment is used to receive and demodulate telecommand signals, to transmit telemetry signals, and for ranging.



The transponder design will include various leading-edge technologies such as low noise amplifiers (Noise figure: 2.5dB), SAW filters to achieve excellent band-rejection performance (60dB min. ±2MHz from center frequency), threshold extension FM demodulation to achieve high sensitivity, and hybrid microwave ICs to minimize equipment size and weight, plus high-efficiency high-power amplifiers (RF output: 6W min.).

As one of the world's leading suppliers of satellite transponders, NEC has contributed to a number of international programs, supplying hundreds of advanced transponders for INTELSAT-IV, IV-A and VI series of communications satellites.

NEC has also integrated and supplied all the transponders for Japan's communications satellites, including the world's first two Ka-band satellites, and various TT&C (tracking, telemetry and command) transponders.

Additionally, NEC was awarded a contract to develop and integrate high reliability transponders for BS-3a and -3b, Japan's next generation of direct broadcasting satellites.

ALL-SOLID-STATE UHF TV TRANSMITTERS.

The latest 30kW UHF TV transmitter from NEC sets a new standard for high output power in all-solid-state design.

The 30kW transmitter incorporates many enhancements including high-performance exciters, powerful transistor power amplifiers, low-loss RF combiners and high-efficiency switching regulators.

The 1.2kW transistor power amplifier, utilizing reliable, high-power and high-gain (120W typical and 7dB min. at 860MHz) bipolar transistors which were developed in-house, features a remarkably reduced component count—only 1.7 times larger than the conventional 300W PA.

Compared to tube types, the new transmitter features greatly enhanced economy and reliability. Safety and maintainability are also improved, while power consumption is reduced by approximately half.

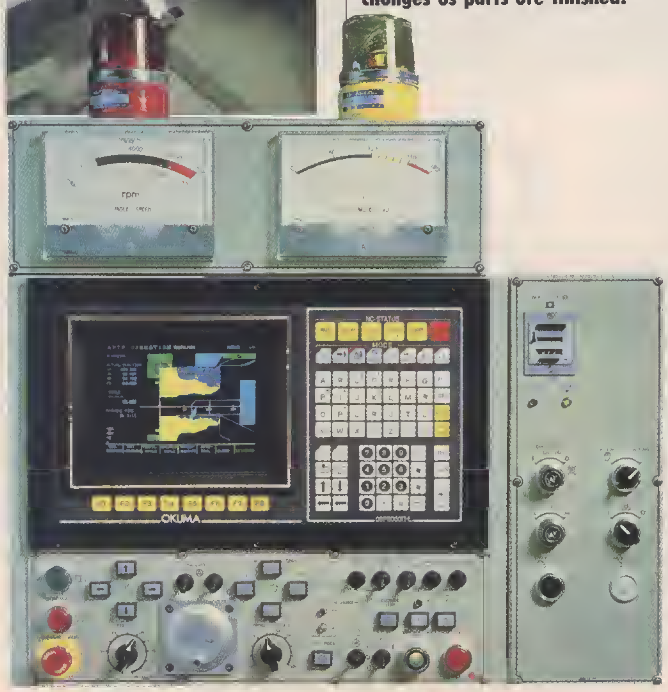
NEC's new all-solid-state UHF TV transmitter series includes 15kW, 10kW, 5kW and 3kW models. A 30kW system is already in satisfactory operation.

NEC

DESIGNING FOR FLEXIBILITY

MINOKAMO—Japanese machine tool manufacturers have been content to leave the giant machining centers favored by major buyers, such as aerospace and automobile companies, to U.S. and European competitors. Instead, they have vigorously moved into global markets with small and mid-sized numerically controlled (NC) machines, especially targeting the thousands of machine shops in the United States and Europe as well as their own country. This strategy has paid off handsomely; Japan now leads the world in the production of NC machine tools.

Last year Japan produced close to $6 billion worth of machine tools, about 67% of them numerically controlled machines useful for making multiple parts in small lots, according to Yoshio Otaka, manager of the Japan Machine Tool Builders Association's technical department in Tokyo. Some 60% of machining in Japan is now done by small and medium-sized companies, he says, and these shops favor more flexible machines suited to short runs.



Okuma in Oguchi is the first of the Japanese machine tool companies to produce its own control computers for guiding computer-numerically controlled (CNC) machines (left). Its Compus A computer (below) is capable of controlling a group of machines, and can direct tool and workpiece changes as parts are finished.

About 30% of Japan's machine tools are exported, mainly to the United States. The devaluation of the dollar is having a big impact on Japanese vendors, says Otaka, so they are responding by putting more production into the U.S., increasing automation in domestic plants, and raising the sophistication of their machines. Okuma (Oguchi), for example, now offers NC lathes and machining centers with submicron accuracies. "We began shipping more sophisticated machines at the end of last year, and immediately received repeat orders," says Isao Tokoro, manager of the North American section of the export group.

by Robert Haavind

Perhaps 80% of U.S. machine tool sales are to small and medium-sized machine shops, says Kazuo Nakatani, regional manager (Marlborough, Mass.) for Yamazen USA, a leading Japanese machinery exporter. To service such a fractionated market, Japanese makers have aimed for a mean time between failures for their machines of 5000 hours, claims Nakatani. Also, many machines have self-diagnostic features, so that when trouble does occur the user can tell the service center what's wrong, or even fix it with advice over the phone. If a serviceman is needed, he is prepared with the right tools and parts, cutting the average maintenance call to an hour.

Skillful use of automation and flexible machining centers helps Japanese machinery companies to keep costs down and to respond quickly to market changes. Advanced techniques developed for making their own parts are quickly incorporated in their machines and marketed to other metalworking shops in Japan, which serve as a testbed for machinery that can then be sold globally. Visits to major Japanese machine tool builders reveal that the trend toward flexible automation has not slowed down. In addi-

At Yamazaki Mazak's factory in Minokamo, automatic guided vehicles (AGVs) deliver workpieces on pallets to conveyors that feed them to the proper machines (left). Each machine works with an automatic tool changer that can be rotated rapidly so a new tool can be inserted (top); that way, one machine can perform several operations on a part. Finished parts are taken by AGVs to either a shipping or an assembly area (above).

PHOTOGRAPHS BY ETHAN HOFFMAN

tion, Japanese industry is pushing forward in machining sophistication as machinery makers explore new uses for lasers, computers, and other advanced technologies.

Yamazaki Mazak takes pride in its 500,000-square-foot machinery factory in Minokamo (soon to triple in size). Still, Bruce Dozier, engineering department manager, apologizes for "outdated" machines built with three-year-old technology and for relatively inflexible automatic guided vehicles. Dozier is an aberration in a Japanese company: an American executive. All of these features will soon be upgraded, he assures visitors as he leads them around the plant on a catwalk above the machining floor (put in so that guided tours, which are frequent, don't disrupt work).

Despite the disclaimers, however, the level of automation in the Minokamo plant is unusually advanced, even in Japan. Lines of machines are fed with workpieces carried down conveyors on plastic pallets ("wood generates dust and splinters," Dozier explains). Automatic tool changers switch cutting tools under computer control in seconds. Large lines are run by IBM Series/1 computers. Pallets

carrying new workpieces or machined parts are switched at the end of each conveyor by automatic guided vehicles. If more machining must be done on the parts, they are automatically delivered to another line; if not, they're sent to an assembly or shipping area.

Since 1983 this plant has maintained over 90% machinery utilization while running six days a week, 24 hours a day, Dozier claims. The workers generally do maintenance or repair work, or load and unload pallets, rather than run machines. Enough parts are manually loaded on pallets at the end of the second shift so that machining can continue through the night (with lights out). Designers are limited to using 66 tools for fabrication of parts, says Dozier, so that 14 spare tools can be included in an 80-tool automatic tool changer. Thus tools that break most often, such as small-diameter drills and taps, can be immediately replaced.

Typical of the flexible systems being assembled in Yamazaki's headquarters in Oguchi is a four-machine cell (costing about $500,000) that does standard turning plus secondary machining operations (drill, mill, tap, bore). Workpieces are lifted into position by robots with a capacity of either 120 or 500 pounds. A servo allows z-axis contouring with simple one-line instructions, according to Dozier. This cell is controlled by a DEC PDP 11/24 computer. A full flexible manufacturing system would consist of 14 such cells, he explains, plus automatic guided vehicles.

Conditions in the Oguchi plant illustrate the attention to detail so prevalent in Japanese factories: it is much cleaner than most U.S. machine shops, and temperature is kept within 2° C to give a more stable workpiece. In the precision machining room, where finishing operations and measurements are done, temperature is controlled to 1° C.

Dozier, who worked for several years in the U.S. machine tool industry, says the difference between the two countries is "like night and day." The Japanese invest heavily in machinery and automation: Yamazaki spent $30 million last year to upgrade an older plant, for example. When new ideas come along, management's attitude is "Let's give it a try," says Dozier. By contrast, he found American management to be quite cautious, and slow to invest in new technology. In fact, a complaint heard at a number of machine tool companies is that U.S. firms are less interested in buying advanced machine tools than firms in Europe and Japan.

A seven-year flexible manufacturing system (FMS) project completed last year at the Mechanical Engineering Laboratory in Tsukuba (Japan's science city) helped increase the precision of Japanese machinery and led to other technology advances. The project cost about 13.7 billion yen (about $55 million before the recent devaluation of the dollar) and involved some 20 companies. Two types of laser machining technologies came out of this national FMS project, according to Tomohiko Ono, director of the production engineering department: 20-kilowatt carbon dioxide lasers for welding, cutting, and surface hardening, and 300-watt yttrium-aluminum-garnet (YAG) lasers for deburring, chip breaking, and internal cutting. The high-power CO_2 laser was developed by Mitsubishi Electric, the YAG laser by NEC. In the FMS test-bed, an optical link allowed a 10-kW laser beam to cut sheet metal in one place or to surface-harden a gear in another. Mechanical systems were also devised so different workpieces could be moved under a fixed laser beam.

To produce complex shapes using hot isostatic pressing (HIP), a new method using preheating of metal powders was devised that cuts process time by a third, says Ono. (HIP is a method of making powder metal parts at high pressure but below the metal's melting point; see HIGH TECHNOLOGY, Sept./Oct. 1982, p. 30.) Another achievement was the development of seven types of modular head units for interchangeability in a machining complex.

Despite such advances, Japan needs to upgrade its capabilities in precision machining even further, says Otaka at the Japan Machine Tool Builders Association. The nation is now moving into the aircraft market, he explains, requiring precise machining of materials like titanium, nickel, and aluminum rather than cast iron or steel. Methods will also be needed for precision machining of ceramics for automobile and aircraft engines. In conventional auto production, tolerances of 10 microns are acceptable, but for a part such as a metal mirror, ultraprecise machining with diamond tools is required to achieve tolerances down to 0.02 micron, according to Otaka. He credits the Lawrence Livermore Laboratories in Berkeley, Cal., with world leadership in ultraprecision machining, while Japan lags far behind in such advanced technologies.

Cutting lightweight nickel and aluminum will also require high-speed machines. Yet Japan's ordinary machines are usually limited to about 500 to 1000 rpm, and its fastest ones might take this to 3000 rpm, says Otaka. The French, world leaders in this area, have reached 60,000 rpm using special magnetic bearings. In laser machining, he points out that although the FMS project raised Japan's capabilities from 5 kW up to 20 kW in CO_2 lasers, U.S. lasers for machining operations are available in the 50–100-kW range and thus can handle tougher jobs.

Otaka sees machine tools as the foundation for industry, yet in his view Japan still remains far behind in many advanced machining technologies. Nevertheless, Japanese machinery makers are using other technology advances to attract buyers. Yamazaki has started to sell laser machines in the U.S. for cutting sheet metal. The company hopes a market will develop for laser cutting of other materials as well, such as plastic, ceramic plates, carpets, glass, or clothing. With a vision system added, says Dozier, lasers could also be used for welding. Okuma is developing sensors that measure changes in cutting force to help prevent tool breakage. It's also the first of the machinery companies to build its own numerical control computers, designed to run multiple machines in a flexible cell, claims Hiromitsu Sobue, assistant manager of the export department.

Okuma's Campus A computer is used to control a massive, completely automated flexible machining center for spindles, the most critical part of a machine tool. The 150-foot-long complex has three lathe/milling machines and a deep-hole drilling machine all fed by automatic tool changers. Automatic stackers suspended from tracks along the Oguchi plant's high ceiling move workpieces from one station to the next, and robots move them into position for machining. Finished parts are moved to an adjacent heat-treating station by a numerically controlled gantry loader.

Japanese companies are now moving from NC to CNC, or computer numerically controlled, machines that eventually might take instructions directly from design workstations rather than from today's parts programs. Standardization is currently a problem; machines speak different languages, so no one yet has a satisfactory link between CAD and CAM (computer-aided design and manufacturing), according to Yamazaki's Dozier. Future advances can be expected in this area, as well as in using voice input to direct machines. □

MOVING AHEAD IN COMMUNICATIONS

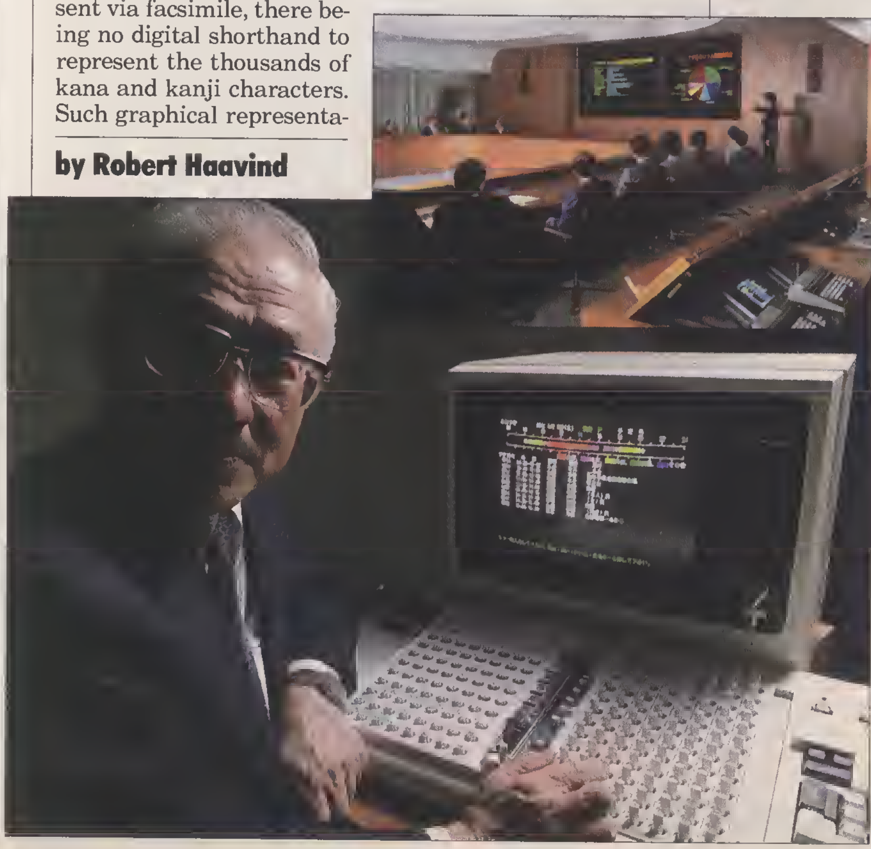
KOBE—Because Japanese executives tend to think about their industries for the long term, many are concerned that their dominance of various markets will be threatened as other nations, particularly their Asian neighbors with lower wage rates, imitate Japan's production methods. So they are building many more of their efficient factories abroad: those for parts and subassemblies primarily in lower-wage nations, and plants for final assembly or more sophisticated manufacturing close to their major markets in the U.S. and Europe. At the same time, many Japanese business leaders are pushing their organizations to build new kinds of strengths, particularly in manipulating and transferring information.

But this is easier said than done. A lack of standardization on such basic matters as digital transmission speed hampers communication between computers and factory machines. In addition, most Japanese documents must be sent via facsimile, there being no digital shorthand to represent the thousands of kana and kanji characters. Such graphical representation requires much more information than ASCII-coded Western text.

by Robert Haavind

Increasingly, the Japanese are gravitating toward fiber optics to transmit data, text, and graphics. In addition to offering much greater transmission capacity than metal cable, fiber optics are immune to electrical noise, such as the voltage spikes that accompany switching of large electric motors. Indeed, factory fiber optic systems appear to be moving more smoothly and rapidly into operation than in other nations. Kawasaki Steel, a leading user of optical networks, is a good example. Computers at Kawasaki's head office in Kobe control operations at the nearby Hanshin Works via a 9600-bit-per-second optical link. Data are sent to large IBM computers at Kobe headquarters from a terminal fed by sensors, from a process control computer, or from an IBM Series/1 computer at the Hanshin site, and commands are sent back to direct operations. If flaws are spotted in steel sheet, for example, instructions can be sent back to reject that section.

At Kawasaki's Chiba Works near Tokyo, over 1000 terminals are connected to a multidrop optical network, according to Shogo Nanbu, manager of system planning and data processing. (In a multidrop network, a large number of terminals are connected to a central computer via a single optical loop.) The communication system that was replaced had over 4000 metal cables crowded into ducts configured in a star network (where each terminal has its own link to the central computer), making expansion difficult, says Nanbu. Circuit



LOU JONES

Left: Toshiba's president, Sugiichiro Watari, uses a specially designed terminal to access all kinds of information about company operations. Top: Executives can quickly scan relevant data in a management decision center at Tokyo headquarters.

quality was low, the plant was unable to meet new needs, and operating and maintenance costs were rising rapidly. The new system is an easily expandable optical network that links about 30 buildings and 50–60 process control computers at Chiba. Optical links from Fujitsu operate reliably 24 hours a day at 48 kilobits per second.

An energy control system operating over the optical network at Chiba is a good example of its effective use. Energy input to production processes, the status of incoming power, and the power from the company's own generators are displayed on a large control panel. Operators can switch generators on or off, or change energy inputs to processes, right from a workstation in the control center using software developed by Nanbu, according to Toshiraru Maezawa, assistant manager of energy coordination. He says it is the most advanced energy control system in the Japanese steel industry.

This fall, says Nanbu , Chiba's local-area network will be converted to Fujitsu's flexible system link (FSL), a token-passing ring LAN that works at 33 megabits per second (versus only 4 Mbps for IBM's token ring LAN). Greater capacity will enable high-speed computer-to-computer and computer-to-workstation links, as well as fax, image, and voice transmission, and teleconferencing to other Kawasaki Steel locations.

Identity cards used with terminals hooked to a computer over optical links at Toshiba headquarters in Tokyo allow employees to charge meals in the cafeteria (as shown) and to automatically register hours worked.

Aside from Japan Airlines' optical network, which covers a greater distance, Nanbu says Kawasaki Steel's is now the largest in Japan. The company claims it has lowered its data communications costs by two-thirds in the last five years while expanding services. The expertise gained in this process is now being spun off in the form of Kawatetsu Systems Development Corp., a subsidiary that will operate out of the Tokyo head office. KSD will offer network planning services for other companies, says Akio Tokita, general manager.

Its first major project will be to digitally link all of Kawasaki Steel's plants and offices, and to connect them to customers, suppliers, and trading companies. Compatibility is a problem, since Kawasaki has both IBM and Fujitsu computers, and outside firms use a wide variety of other systems. One solution would have been to use NTT's Supernet, which links to major trading companies. This would have meant using NTT's standards, and Kawasaki Steel felt it would also be costly. So the company has chosen a different approach.

The major steel companies in Japan have found a quick way to gain compatibility by adopting the interbank protocol developed by the Banking Association of Japan. This Standard Communications Protocol is now open for use by other businesses. All major trading companies have links to one or more of the big steel companies, and they in turn have links to most steel customers. The protocol covers only file transfers between computers, however, and agreements are now being worked out for other types of transactions. As international standards groups reach agreement on higher-level protocols for digital communication (the first three of seven levels are covered by the X.25 standard), Kawasaki Steel plans to install equipment and software to make its network compatible.

Most wide-area transmission is currently by cable or microwave. Optical links are more common for localized or point-to-point systems. But they are beginning to show up in more office buildings as the Japanese make use of their wideband capabilities to speed business communications.

Toshiba became a pioneer in this area in 1984, outfitting its new Tokyo headquarters with an optical LAN that consolidated operations from 11 different locations. About 7000 people work in the complex, and better communications has greatly aided office productivity, according to Hiroyuki Wakai, manager of the information and systems division.

Identity cards are used by employees to check in and out at time clocks, or to charge meals in the cafeteria, with signals from terminals flowing to a central computer over the optical LAN. Ten distributed processing terminals are connected to the central computer, and six document terminals allow standard-size pages to be transmitted in 15 seconds (a time that will soon be cut by a third).

Still, this hardly taxes the capacity of the optical LAN, which has 10 channels, each capable of transmitting 10 Mbps. So Toshiba is developing workstations that would allow more effective use of such a facility. Under development is a 16-bit workstation that will be Toshiba's first with bit-mapped memory and multiple-window architecture. An interface will be provided to allow these workstations to read documents stored in a TOSfile over the optical network. (TOSfile is a system that can hold up to 60,000 standard documents on an optical disc; about 1200 had been sold in Japan at the end of '85, and Toshiba plans to introduce the system in the U.S.) Engineering workstations are also being developed for use with an optical LAN to be installed in a new engineering center in Kawasaki.

Toshiba's president, Sugiichiro Watari, is skilled in using a terminal especially developed for him that provides wide-ranging and up-to-date information about the firm's productivity, products shipped, profits by sector, and so on. Similarly, a management information center at headquarters in Tokyo enables executives to obtain quick visual data to help their strategic planning.

Japanese manufacturers have had great success in mastering factory production methods. It will be interesting to see how well they develop new skills in information technology to strengthen their market leadership even further. □

For further information see **RESOURCES**, *p. 73.*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RADAR

COUNTERMEASURES

The spiral of deception that began in World War II continues to produce better jammers—and better ways to thwart them

The battle of wits never ends in the military laboratories of the U.S. and the USSR, as each side seeks to develop electronic countermeasures—ingenious ways to blind or confuse the radars of its adversary—while trying to make its own systems invulnerable. The latest U.S. fighter aircraft each carry nearly $2 million in self-protection countermeasures. Protection of a bomber can cost 10 times that amount. In total, the U.S. Department of Defense currently spends about $4–5 billion a year for electronic warfare (EW) systems and an estimated $1 billion to gird U.S. radars against Soviet countermeasures. And a major competition for a huge new electronic countermeasure system is under way.

The cat-and-mouse game works like Newton's third law—to every action there is an equal and opposite reaction. Aircraft that use brute-force noise jamming to try to blot out an enemy radar run the risk that an enemy missile can home in on its jamming signal. This has led to more sophisticated jamming techniques, designed to mislead the radar into thinking that the target is somewhere else. That in turn has led to improvements in radar intended to make such deception difficult or impossible.

The scope of present-day EW is reflected in the ALQ-161 integrated defensive avionics system—a $20 million system that weighs nearly 5000 pounds and consists of more than 100 elements—being installed on the U.S. Air Force's new B-1B strategic bomber. Designed and built by the AIL Division of Eaton (Deer Park, N.Y.), it is the most complex and fully integrated self-protection EW system ever built. It even includes a tail-mounted radar designed to detect the approach of an enemy missile and to control the ejection of reflective chaff and flare decoys to protect the bomber. And it has been updated to cope with higher-frequency radar threats that have emerged since the system was first designed a decade ago.

The Air Force and Navy will shortly select two competitive teams of contractors to develop the Integrated Electronic Warfare System (INEWS), an even more advanced self-protection system for the next-generation Air Force fighter and Navy attack aircraft. By 1989 the two services will select a single team for full-scale development, leading to production in 1993 or 1994. The stakes are especially high because INEWS is likely to be the only major new airborne self-protection system developed before the turn of the century, and each system is expected to sell for $2–2.5 million. If the price seems high, bear in mind that the aircraft INEWS is intended to protect will probably cost $40 million each.

INEWS will warn a pilot of threats across a broad spectrum, including laser target designators that operate in the infrared and can illuminate aircraft to guide an enemy missile to its target.

by Philip J. Klass

Furthermore, the system will manage the jammers and expendables (chaff and flares) to make most effective use of all of the aircraft's EW resources. Requirements also specify that the system's architecture be rapidly adaptable to new threats that are likely to emerge before it goes into operational use.

One of the biggest unknowns confronting the two INEWS teams is the amount of "stealth" technology that will go into the Air Force's next-generation Advanced Tactical Fighter and the Navy's next-generation Advanced Tactical Attack Aircraft. To reduce the radar detectability of an aircraft, stealth technology involves such techniques as replacing metals with composite materials and shaping external features to minimize their reflection of radar signals. Because antennas can reflect energy from an enemy radar, the type of antennas selected for INEWS, and their positioning in the airframe, will affect the "stealthiness" of the aircraft. Thus the two INEWS teams will have to work closely with the two aircraft companies selected to develop the new fighter planes.

Cutting losses. INEWS is just the latest twist in a saga that started in World War II, with the birth of radar. Electronic warfare progressed slowly for the next two decades, but then received a painful shot in the arm in the mid-1960s, when U.S. fighter aircraft first encountered the deadly Soviet radar-directed SA-2 surface-to-air missiles (SAMs) in Vietnam. Initially, the U.S. lost up to 14% of the fighter aircraft in a single mission—a loss rate that often claimed half a squadron after five missions. The cramped planes carried no electronic countermeasure equipment; they had no room for bulky jammers, such as those used in Strategic Air Command bombers, or for an EW officer to operate an electronic intelligence (elint) receiver to warn when the aircraft was being illuminated by an enemy radar.

Fortuitously, Applied Technology (Sunnyvale, Cal.) had developed a small semiautomatic elint receiver for use on the Lockheed U-2 spy plane during its reconnaissance flights over the USSR in the late 1950s. In mid-1965 the Pentagon launched a crash program to devel-

Above: HARM missile, just launched from an F/A-18, stores location data on target radar in its memory in case the radar shuts down to avoid detection. Opposite, top: ALQ-131 jamming pod protects F-16 fighters.

op a functionally similar radar warning receiver for fighter aircraft in Vietnam, and selected Applied Technology for the job. (The company was later acquired by Itek, which more recently was purchased by Litton Industries.)

Within a few years, aircraft fighting in Vietnam were outfitted with an APR-25 or APR-26 radar warning receiver. These not only alerted pilots that they were under radar surveillance but also detected, from a change in radar signal, when an SA-2 missile had just been launched. That gave the pilot a few seconds to spot the oncoming missile and take evasive action. Thanks in large part to these and other countermeasures, the loss rate in Vietnam eventually fell to just 2% per mission.

Applied Technology later developed a more advanced receiver, the APR-35, which measured the horizontal angle to an enemy radar, helping the pilots of special mission aircraft to locate the radar, so as to attack and destroy it. But those missions were hazardous, because missile sites were well defended. This prompted the Navy to develop an air-launched missile to home in on the signal from an enemy radar. Called the Shrike, it was hurriedly put into production at Texas Instruments in the mid-1960s.

But the North Vietnamese, undoubtedly aided by Soviet advisers, devised a very simple and effective countermeasure. They turned off their radar transmitters periodically, to deprive the Shrike of signals to home in on. This countermeasure later prompted the Navy to develop a high-speed antiradar missile called HARM, now being produced by Texas Instruments and entering the Navy/Air Force inventory. HARM measures the horizontal and vertical directions to an enemy radar while it is transmitting, to compute its approximate location and store it in guidance computer memory in case the enemy radar shuts down briefly. When the radar comes back on the air, HARM updates its information. The missile received its baptism of fire in late March when Libya fired Soviet SA-5 antiaircraft missiles at U.S. Navy jets over the Gulf of Sidra, prompting them to launch two HARM missiles. Whether the SA-5 radars were destroyed or simply switched off, no more SA-5s were subsequently fired.

Improved jam. Radar warning receivers are essentially passive devices. To complement them in a more active fashion, engineers in the mid-1960s developed modified versions of Strategic Air Command jammers that could be carried in pods suspended under a fighter aircraft wing. Later in the decade, the Air Force decided to fund development of a pod specially designed for fighter aircraft and capable of jamming radars operating in several different frequency bands. This pod, called the ALQ-119, was designed and produced in large quantities by

Westinghouse (Baltimore), and remains in use today on older fighter aircraft. A newer and more capable Westinghouse jamming pod, the ALQ-131, entered production in the late 1970s, and is now used on the Air Force's newest fighter, the F-16.

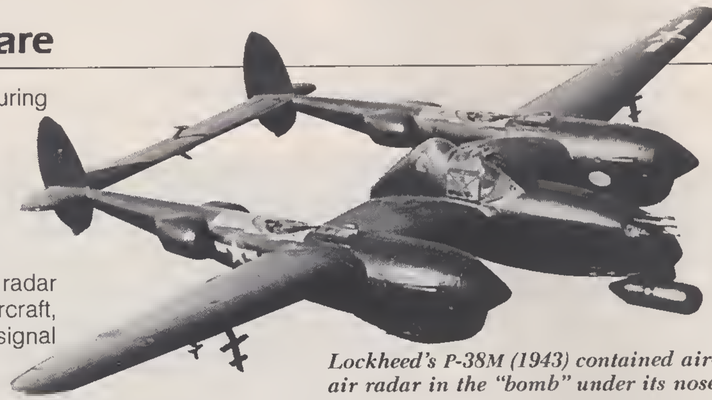
As the war in Vietnam was winding down in 1972, the Navy introduced a "standoff jammer" aircraft, the EA-6B, which can loiter safely beyond range of enemy missiles and radar-directed antiaircraft guns as it jams enemy radars and missile guidance command signals. The new EW aircraft was a modified version of the Navy's two-man A-6B attack plane, built by Grumman, with an elongated fuselage to accommodate two electronic warfare officers.

The EA-6B normally carries five external jamming pods—two under each wing and one below the fuselage. Pods come in seven versions, each covering a different frequency band, so the plane can be outfitted according to the most likely threat on each mission.

By the end of the Vietnam War, the use of radar warning receivers, self-protection jamming pods, chaff, and standoff jammers had significantly reduced the effectiveness of the Soviet SA-2. Whereas in the early days of conflict the North Vietnamese needed to fire only one or two SAMs to destroy a U.S. aircraft, by the end of the war they required more than 60. The introduction of electronic countermeasures during the later phases of the 1973 Mideast War produced equally dramatic results.

The success of the Navy's EA-6B in Vietnam convinced the Air Force that it should acquire similar dedicated jamming planes to protect its tactical aircraft against the growing number and mobility of Soviet radars and antiaircraft weapons in central Europe. Current estimates indicate that more than 10,000 Soviet radar-directed antiaircraft guns and several thousand radar-directed SAM launchers are now poised in central Europe, many of them on mobile vehicles. Recognizing that fighters needed an escort jamming platform that could keep pace with them at supersonic speeds, the Air Force opted for an existing plane, the F-111A, and picked Grumman to outfit it with a

The origins of electronic warfare



Lockheed's P-38M (1943) contained air-to air radar in the "bomb" under its nose.

NATIONAL AIR & SPACE MUSEUM/SMITHSONIAN INSTITUTE

At the same time that radar was being introduced during World War II to give defenders early warning of air attacks, researchers on both sides recognized that the technology—employing a very sensitive receiver to detect weak echoes of radio-frequency energy reflected from a distant target—would be relatively easy to overwhelm and confuse. If the target itself should transmit a more powerful signal at the same radar frequency, this could appear to be a much larger aircraft, or perhaps several aircraft; if powerful enough, the signal could even overwhelm the radar receiver, just as a bright light washes out the image in a TV camera.

Initially, both sides depended so heavily on radar to warn of air attack that each hesitated to introduce such countermeasures, for fear that the enemy would catch on and do likewise. But the British broke this stalemate in April 1942, in an effort to degrade the deadly effectiveness of German air defenses. The Royal Air Force outfitted a squadron of fighter aircraft with a jammer called Moonshine, designed to make each airplane appear to be a formation of British bombers. The object was to prompt the Germans to dispatch many interceptors toward each of these "spoofers," which could then use their speed to escape while slower, more vulnerable bombers faced less opposition. To accomplish this objective, the Moonshine jammer simply amplified each pulse received from a German radar and transmitted it back, causing a large blip to appear on the radar screen. Moonshine was very successful, prompting both sides to use jammers thenceforth.

Allied and Axis researchers soon developed a very different type of countermeasure, and again each held back its use in the hope that the enemy had not yet conceived the idea. In the U.S. it was known as chaff, while the British gave it the code name "window," the Germans termed it *Düppel* (after Düppelsee, the lake where the concept was studied), and the Japanese referred to it as *giman-shi* ("deceiving paper"). The earliest versions consisted of small strips of thin paper covered with aluminum foil. When a bundle of chaff was ejected from an aircraft in flight, the many thousands of strips dispersed to form a cloud that reflected radar energy, creating many spurious targets. The Japanese were the first to use chaff, during the battle for the Solomon Islands in May 1943. With the cat out of the bag, the Royal Air Force first used it in a night raid on Hamburg on July 24–25, 1943.

A few weeks later, the Germans, who had themselves experimented with chaff and had anticipated that it might be used against them, began to introduce electronic counter-countermeasures. These exploited the doppler effect—the frequency shift of reflected radar energy in proportion to the speed of the reflecting object—allowing bombers to be distinguished from slow-moving clouds of chaff.

Meanwhile, designers continued to work on active jammers. They faced the handicap of not knowing what new generations of radars were in development in the laboratories of their adversaries. That placed a great premium on what is now called electronic intelligence (elint) or, more specifically, signals intelligence (sigint). Beyond detecting new types of radar, elint served to determine the location of enemy radars, the extent of their coverage, and possible blind spots owing to such things as mountainous terrain. For example, on March 6, 1943, the U.S. first used a "ferret" aircraft equipped with very sensitive radio-frequency receivers, to determine that the Japanese had installed air defense radars on Kiska Island in the Aleutians, and to assess their coverage. (For the past two decades, both the U.S. and the USSR have also used the orbital equivalents—ferret satellites).

As jamming became more common, radar operators on both sides devised a relatively simple countermeasure. They merely shifted to a different operating frequency, which enabled the radar to distinguish its own echoes from a jammer's signal. Modern radars are designed to do this automatically.

Improvements in radar techniques and countermeasures continued after the war; only the adversaries were different. Over the past 40 years, whenever the Soviets have introduced a new type of radar, the U.S. has developed a new "black box" to counter it, and vice versa.

somewhat more automated version of the countermeasure system used on the EA-6B. To avoid compromising the plane's speed, all jamming equipment is mounted internally rather than in external pods. Because this allows room for only one EW officer (riding in the copilot's position), the modified aircraft, called the EF-111A, required more automated systems. Altogether, 42 of these planes are now in service. They played an important role, together with the EA-6B, in the recent U.S. strike against Libya in April.

Mixed signals. If a radar warning system had only to analyze the signals from a handful of radars, its task would be relatively easy. Long-range early-warning radars can be identified by the lower frequencies that they use to achieve maximum range in rain or snow, and they typically emit only a few hundred pulses per second for maximum effective range. By contrast, a radar used for target tracking and missile guidance typically operates at higher frequencies and radiates many hundreds of pulses per second. And an airborne radar used by an interceptor normally operates at still higher frequencies and at more than 1000 pulses per second. To complicate matters, new Soviet radars use a variety of techniques, such as changing their frequency rapidly and altering their pulse rates, to frustrate U.S. electronic warfare systems.

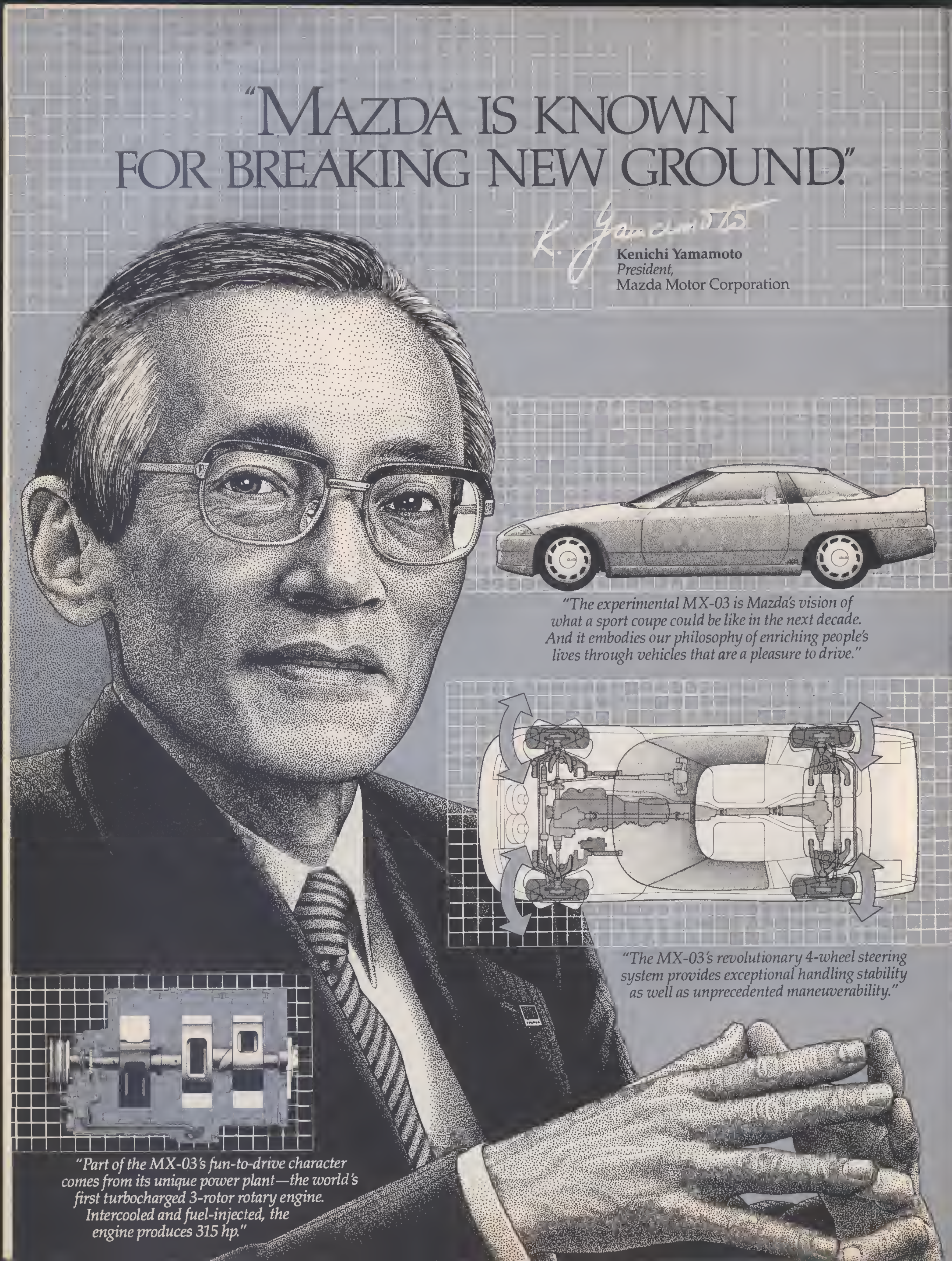
Fortunately, digital computers—well suited to correlating and analyzing signals at high speed—can determine which pulses come from what type of radar at approximately what bearing. By the mid-1970s, suitable computers had become small enough for use in radar warning systems. Dalmo Victor (Belmont, Cal.), recently acquired by Singer from Textron, was the first to introduce digital computers into new-generation radar warning systems.

Once such a system has analyzed each radar signal, it refers to prestored information to determine the radar's function and mode, and to assess the threat it poses to the aircraft. This information, together with the approximate bearing to the radar, is then displayed on a small cathode-ray tube in the cockpit. When a new type of enemy radar is introduced, the system's computer can be reprogrammed in the field to enter its operating characteristics.

Active deception. One of the immutable laws of electronic warfare is that an aircraft equipped with a capable radar warning system can always detect the powerful signals from an enemy radar before the ground radar station can detect the weak echoes from the aircraft. But after a radar warning system has detected a signal from an early warning/air surveillance radar, a pilot can never know for sure whether the radar has yet detected his aircraft, because he doesn't know the capabilities of the system or its operators. However, he knows with certainty that if he activates a "brute-force" noise jammer he will surely alert the radar operator to his aircraft's presence. And if he continuously operates such a jammer, he offers the enemy the opportunity to launch a missile that can use the jamming signal to home in on the aircraft, a technique called home-on-jam.

These liabilities of brute-force jamming have led to "deception" jamming techniques, intended to give a false reading of the target's whereabouts. A radar beam produces the strongest echo when its center hits the target. Thus the direction of the main beam at that moment is presumed to be the bearing

The Air Force's EF-111A (top left) and the Navy's EA-6B (bottom) can loiter safely out of missile and gun range while jamming enemy radars and missile guidance signals. They also have enough speed to keep pace with the fighters that they protect. Top right: ALR-77 antennas mounted on each wingtip of the Navy's P-3 provide 180° of unobstructed radar coverage.


"MAZDA IS KNOWN FOR BREAKING NEW GROUND."
K. Yamamoto
Kenichi Yamamoto
President,
Mazda Motor Corporation
"The experimental MX-03 is Mazda's vision of what a sport coupe could be like in the next decade. And it embodies our philosophy of enriching people's lives through vehicles that are a pleasure to drive."
"The MX-03's revolutionary 4-wheel steering system provides exceptional handling stability as well as unprecedented maneuverability."
"Part of the MX-03's fun-to-drive character comes from its unique power plant—the world's first turbocharged 3-rotor rotary engine. Intercooled and fuel-injected, the engine produces 315 hp."

TODAY, IT'S A SPORTS CAR SO ADVANCED, ITS REAR WHEELS ACTUALLY HELP YOU STEER THROUGH A TURN.

Perhaps the concept of rear-wheel steering leaves you a little puzzled. If so, you're in good company. Because until recently, even the world's largest automakers considered this highly sophisticated technology simply a theoretical possibility. Yet in designing the new-generation RX-7, Mazda engineers have taken a major step towards turning that possibility into reality.

For beneath the RX-7's stunning shape, you'll find the Dynamic Tracking Suspension System. Under cornering loads, this unique rear suspension automatically adjusts rear wheel alignment to help you steer through turns. The result? More agile, more precise handling. And a sports car that responds to your commands as though it had anticipated them.

SHAPING THE FUTURE OF THE AUTOMOBILE—ONE INNOVATION AT A TIME.

As remarkable as the Dynamic Tracking Suspension System is, it's merely one expression of Mazda's commitment to innovations in technology.

Innovations like the rotary engine—this century's only new production automobile power plant. Others had explored its development before, only to come away empty handed. But through six years of patient research, Mazda engineers solved the riddles of the rotary. Then continued to make refinements which have led today to what may be the ideal sports car power plant.

Yet a still higher level of rotary engine sophistication and performance is on the horizon. For with the recent introduction of the experimental MX-03, Mazda engineers have unveiled the world's first turbocharged three-rotor rotary engine. This advanced two-stage-turbocharged, intercooled power plant produces 315 horsepower. More than some race-car engines.

And to help tomorrow's drivers handle this level of power, Mazda engineers have also endowed the MX-03 with a revolutionary, electronically controlled, speed-sensing, 4-wheel steering system. Providing an exceptional combination of high-speed stability and unprecedented low-speed maneuverability, the system represents nothing less than a quantum leap in the science of vehicle dynamics.

The new Mazda RX-7—a combination of innovative technologies produces a new level of sports car performance.

MAZDA'S U.S. PLANT—*An update.*

Construction of Mazda's new \$450 million plant in Flat Rock, Michigan is continuing on schedule with equipment already being installed in the paint shop. In addition, hiring procedures have begun with an astounding 143,000 people requesting application forms for 3,000 jobs. Automobile production is scheduled to begin in the fall of 1987.

TECHNOLOGY DESIGNED TO ENHANCE THE LIVES OF THOSE IT TOUCHES.

Over the years, Mazda has followed many paths in its pursuit of innovation. Yet the true goal of this pursuit has not simply been technology for its own sake. Instead, Mazda's goal has been to develop technologies that will enrich people's lives by making its vehicles easier and more fun to drive. And that's one path from which Mazda will never stray.

For a free copy of the 1985 Mazda Annual Report and/or your choice of a 1986 RX-7, 626, 323 or B2000 product catalog, write to: Mazda Report/Catalog Offer, Box 5960-CO, Orange, CA 92668. Or call this toll-free number: 800-521-1055

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to the target. But because of imperfections, most radar antennas also emit two or more unwanted beams called sidelobes, at least one on either side of the main beam. So weak are these beams that they can detect aircraft only at very close range; but an aircraft's EW system can detect the sidelobes at long distance. The airborne EW system can also determine the scan rate, as well as the angle between the main beam and the sidelobes, and hence can predict when a sidelobe will be aimed at the aircraft.

If the aircraft's jammer transmits a strong radarlike pulse at that instant, the ground radar receives a stronger signal from the sidelobe than from the main beam. This misleads the radar operator into thinking that the target is located where the main beam is pointing. If the sidelobe is displaced from the main beam by 10°, say, and the aircraft is 200 miles away, this creates a discrepancy of about 35 miles between the target's true location and the radar-perceived position. Interceptor aircraft using the radar to zero in on the target are badly misdirected.

That explains why in recent years the U.S., and presumably the USSR also, have concentrated on improved antenna designs with greatly reduced sidelobes for new-generation air surveillance radars. Westinghouse has become a leader in ultralow-sidelobe antenna technology; its current AN/TPS-70 system is an upgraded version of the well-tried AN/TPS-43 transportable antenna, which remains in heavy demand abroad. Alternatively, designers can frustrate deception jamming aimed at sidelobes by giving each radar pulse its own "fingerprint," which makes the signal more difficult for a jammer to mimic instantaneously.

Another target of deception jamming is the class of radar designed to track a single target automatically; it is used to aim antiaircraft guns or to guide missiles. In order to track a fast-moving target and to distinguish its echoes from spurious ones that bounce off the ground or other aircraft, the radar uses "range gate" circuitry, which in effect remembers the target's last measured range and estimates what the range will be when the next echo is received. Using this forecast, the radar receiver is turned on only when the target echo is expected to arrive.

Naturally, the radar presumes that the strongest signal received during the brief time the radar receiver is turned on will be the echo of the main beam returning from the target. To exploit this, the aircraft's EW system radiates a moderately strong look-alike pulse—immediately after receiving a pulse from the radar—that will arrive when the range gate is still open. The range gate locks onto this look-alike pulse. Then, in a technique called range gate stealing, the aircraft's EW system gradually delays the look-alike pulse, to draw the radar range gate away from the aircraft's true location. When the range gate has been shifted away sufficiently, the airborne EW system stops radiating, leaving the radar confused and requiring operator assistance to relocate the target. By then, the aircraft may have moved beyond the radar's effective range or may have come close enough to launch its own weapons to destroy the radar.

A different technique aims to befuddle the circuitry that tracking radars use to determine a target's horizontal direction and elevation. For many years, such radars used what is called conical scan. In this technique, the small antenna spins about its boresight axis (the imaginary line between antenna and target), causing the beam to sweep in a circular pattern to cover the area around the target. With each revolution, the amplitude of the echo varies according to the target's position relative to the boresight axis—whether slightly above or below, or to the left or right—so that the antenna can be adjusted to stay on track.

Digital computers are crucial in making the best use of airborne jamming resources.

The aircraft's EW system can readily determine the antenna's spin rate, by noting the amplitude variation of the pulses it receives from the radar—corresponding to that of the echo being detected by the radar. The airborne jammer then transmits look-alike pulses, radiating its strongest ones when the aircraft senses the weakest, and vice versa. Because the amplitude modulation of these jammer pulses is the reverse of what the radar would normally receive, the radar's tracking circuit concludes that the target is above the boresight axis when it is in fact below, or vice versa. This causes the radar to become confused and to lose its target when the jammer shuts down.

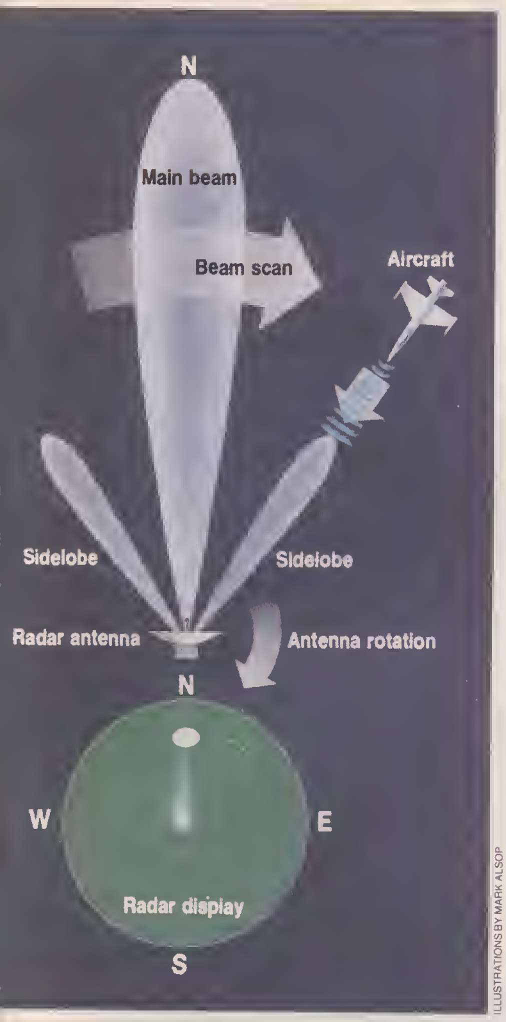
Because of this vulnerability, conical-scan radars are being replaced with a more complex and costly type, called monopulse, that is far more difficult to confuse. Monopulse radar, originally developed by AT&T's Bell Laboratories (Whippany, N.J.) for the Nike-Hercules air defense missile systems in the mid-1950s, in effect uses four beams. By comparing the echoes' strengths or arrival times, it can determine a target's position from a single set of echoes.

One technique devised to counter monopulse is called blinking. It requires two aircraft to operate as a team, with their jammers synchronized by radio link. When a monopulse radar is encountered, the two planes alternate in emitting look-alike pulses. The monopulse radar determines the position of aircraft A, but the next pulse makes it appear that the target has shifted to the location of aircraft B, perhaps several hundred feet away from A. Confronted with the apparent shifting position of what the radar believes to be a single target, the radar's simpleminded tracking circuit concludes that the target must be halfway between the two positions. So it aims its antiaircraft guns accordingly—and presumably misses both aircraft. This technique is difficult to use, however, and has proved only moderately successful. General Electric (Utica, N.Y.) has recently demonstrated a more effective—and still secret—technique for countering monopulse radars.

These examples have focused on techniques for defeating a single radar at a time. But an aircraft must often contend with several different radars. In fact, the Soviets interconnect many of their ground radars so that all of them must be jammed or deceived simultaneously to negate their effectiveness. Standoff/escort planes such as the EA-6B and EF-111A can carry only a few jammers. Fighter aircraft outfitted with self-protection EW systems have even fewer, and their one-man crews are burdened with many other pressing duties. This explains why the digital computer, which assumed a key role in radar warning systems, is becoming equally crucial in making the best use of limited airborne jammer resources.

A spectrum of tricks. One of the more effective countermeasures against radar is to take advantage of the earth's curvature, which can hide very low-flying aircraft until they are close to a ground-based radar. To foil Soviet use of this tactic, the U.S. has developed and deployed Airborne Warning and Control Systems (AWACS) aircraft—modified Boeing 707 jetliners outfitted with giant radars that can spot low-flying aircraft despite clutter echoes from ground terrain. The USSR has recently deployed a similiar type of aircraft.

While shielded from ground radar, low-flying aircraft become more vulnerable to relatively inexpensive short-range missiles that use infrared detectors to home in on the hot exhaust plumes from jet engines. Such missiles,



By transmitting a strong radarlike pulse when in direct view of a radar's weak sidelobe beam, a jammer can convince the radar operator that the white blip indicates the aircraft's position.

however, cannot "see" through clouds or heavy precipitation, and thus are limited to use in fair weather. The U.S. Navy pioneered infrared guidance techniques in the 1950s, for use on the Sidewinder air-to-air missile during close-in aerial combat in good visibility, and the USSR soon developed its own equivalents. Later the U.S. applied infrared guidance to the Redeye surface-to-air missile for use against low-flying aircraft. But the deadly effectiveness of infrared guidance for this mission was first demonstrated during the 1973 Mideast War by the Soviet SA-7, launched from armored vehicles by Egyptian and Syrian forces.

Fortunately for the Israeli Air Force, the U.S. had already developed, and could quickly supply, a moderately effective countermeasure in the form of small flares ejected from the aircraft dispenser normally used to launch chaff. Such flares, now manufactured mainly by Tracor-MBA (San Ramon, Cal.), ignite immediately after ejection. Their intense heat generates infrared energy to lure the missile away from its target. But the timing of the ejection is critical: too early, and the missile might not detect the flare; too late, and the missile might be too close to divert from the aircraft.

To counter Soviet decoys, newer U.S. heat-seeking missiles employ more sophisticated sensors that operate at two different wavelengths. This enables the guidance system to discriminate better between the infrared energy emitted by a jet engine and that radiated by a flare. Raytheon (Lexington, Mass.) and Ford Aerospace (Newport Beach, Cal.) supply such sensors for the AIM-9 missile.

Another countermeasure against infrared-guided missiles exploits the fact that they use a conical-scan technique similiar to that of earlier tracking radars. Some low-flying U.S. Army helicopters, which are especially vulnerable to Soviet SA-7s and newer-generation SA-9s, are equipped with active infrared jammers that radiate infrared energy specially modulated to confuse the missile's guidance system. Such jammers are produced by Sanders Associates (Nashua, N.H.), Northrop's Defense Systems Division (Rolling Meadows, Ill.), and Loral's Electro-Optical Systems Division (Pasadena, Cal.). Recent photos of Soviet helicopters operating in Afghanistan reveal that they too are being outfitted with infrared jammers, to counter heat-seeking missiles in the hands of the Mujahideen. And El Al Israel Airlines has equipped its air transports with such jammers to protect them against terrorist missile attacks during takeoff and landing.

A new class of threat is in prospect in the optical part of the spectrum. During the latter phases of the war in Vietnam, the U.S. developed a new guidance technique for directing bombs precisely to their targets on the ground. An operator on the ground pointed a low-power laser, radiating in the near-infrared around 1 micron wavelength, at the target several miles away. The bomb, outfitted with a special guidance system, homed in on the reflected energy.

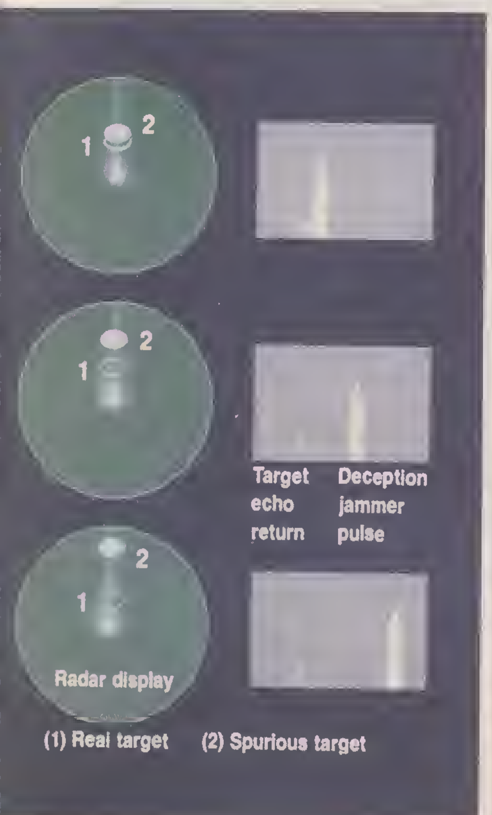
This raises the possibility that antiaircraft missiles might use a similiar guidance technique. An enemy operator on the ground, using a simple gunsight, would aim a low-energy laser at an approaching aircraft, and a missile could then home in on the reflected energy. Because the near-infrared laser beam is invisible to the human eye, the pilot would get no warning of impending attack. To cope with this, the U.S. Army has funded development of the AVR-2 laser warning sensor by Perkin-Elmer (Norwalk, Conn.). Installed on Army helicopters, it can warn pilots to use evasive maneuvers to frustrate the laser operator.

Assuming that cleverness is an inexhaustible resource, the back-and-forth game that began nearly half a century ago is likely to continue indefinitely. Electronic countermeasure systems have benefited enormously from the availability of high-speed microprocessors, but the same computer-on-a-chip that has aided the designer of airborne countermeasures has also allowed guided missile designers to endow their weapons with greatly increased abilities to cope with those countermeasures. These weapons are certain to become smarter during the 1990s, through artificial intelligence techniques only now beginning to emerge from the laboratory. But such techniques will also find use in electronic and electro-optical countermeasures. And after that will come another round of countermeasures and counter-countermeasures. □

Philip J. Klass has covered the aerospace/defense avionics field for three decades for Aviation Week & Space Technology *magazine.*

For further information see **RESOURCES**, *p. 73.*

ILLUSTRATIONS BY MARK ALSOP



In range gate stealing, a plane transmits deception pulses that radar mistakes for its echo. By delaying successive pulses, the aircraft pulls the radar farther away from the plane's true position.

NATURAL GAS LETS TRUCKS RUN CLEAN

Stricter pollution limits may boost the appeal of methane power

Natural gas is emerging as an alternative fuel that enables diesel-powered trucks to meet tightening U.S. pollutant-emission standards. Companies in the U.S., Canada, Italy, and New Zealand are developing dual-fuel engines which, they say, combine the strength and efficiency of diesel engines with the clean-burning characteristics of methane gas. These hybrid compression/ignition engines, burning a mix of approximately 80% natural gas and 20% diesel fuel, also boast reduced noise levels—another factor facing tougher regulation by the federal government.

So far, engine makers have complied with Environmental Protection Agency (EPA) emission standards by sweetening conventional diesels with improvements like turbochargers. They are developing computer-controlled fuel injection for more precise fuel management, and ceramic engine parts to reduce emissions by improving efficiency. And they are experimenting with exhaust-system particulaté traps, even though the devices could add $5000 to $6000 to the price of heavy trucks and their long-term durability is questionable.

But marginal improvements may be inadequate for meeting the new regulations. In 1988 the EPA will limit heavy-truck particulate emissions to 0.6 gram per horsepower-hour (g/hp-hr), dropping to 0.1 g/hp-hr by 1994. Nitrogen oxide emissions, currently restricted to 10.7 g/hp-hr, drop to 6 g/hp-hr in 1988 and 5 g/hp-hr in 1991. At the same time, heavy-truck engine noise levels will drop to 80 decibels in 1988 from the current 83-dB.

by Jeffrey Seisler


KYE CARBONE

"It may not be practical to adapt some high-emission diesels to meet the 1988 particulate limit," says Karl Springer, director of emissions research in the engine and vehicle division at Southwest Research Institute (San Antonio, Tex.). "Some models may even be taken off the market."

Thus, proponents of methane-fueled vehicles—including the natural-gas industry and some engine equipment makers—see the new truck emission requirements as another opportunity to promote their concept. The first big drive for alternate vehicle fuels coincided with the fuel crises of the 1970s. But because the United States government offers no incentives for alternate-fuel development, and because the public generally lost interest when gasoline prices stabilized and later declined, natural-gas vehicles didn't catch on. Today there are only about 30,000 natural-gas vehicles in the U.S., accounting for less than 1% of the nation's total vehicle fleet.

Yet a gallon-equivalent of natural gas costs 35–85¢—still lower than diesel fuel despite recent price decreases to less than $1. And natural gas yields comparable engine performance. Trans Gas Services in New Zealand, where methane vehicles are more prevalent, guarantees its engines will deliver at least 95% of the performance of their diesel-fueled counterparts. What's more, particulates all but disappear with methane fuel, and tests for the Department of Energy and others show it meets the most stringent EPA and California Air Resources Board requirements for other emissions.

Two types of dual-fuel systems are currently available for heavy trucks. One uses a fixed ratio of about 20% diesel and 80% methane; it can be manually switched to operate on diesel fuel only if methane is unavailable. The second dual-fuel method, promoted by Controlled Fuel Systems of Stuart, Fla., varies the ratio of natural gas to diesel depending on engine load. Under full-load conditions the engine uses only about 6% diesel fuel, capitalizing on the higher octane rating of methane for greater engine power. As the engine slows to idle, the fuel mixture changes to 100% diesel, since the fuel both outperforms methane and

complies with EPA emission standards under low engine loads. This method burns an average of 80% methane and 20% diesel, but it optimizes both diesel and methane by using a higher mix of the fuel that performs best under particular conditions.

It is also possible to power an engine on pure methane if spark plugs are used for ignition. This makes pure methane a natural alternative fuel for spark-ignited gasoline engines common in passenger cars and light trucks. But diesels—which do not need spark plugs since diesel fuel ignites spontaneously when engine compression raises its temperature to 536° F—are used in industrial applications because of their durability and inherent efficiency; diesels transform about 35% of their fuel's latent energy into power, compared with about 28% in high-efficiency gasoline engines. Compression ignition of methane occurs at 1292°—unattainable by engine compression. Thus, in dual-fuel engines the diesel fuel is necessary to start combustion. Spark-ignition systems can be added to diesels, permitting them to burn pure methane. But the cost of this modification—about $5000—limits it to engines intended for urban areas, where soot emissions are most critical. Mexico City officials, for example, are considering changing 5000 city buses to spark-ignited natural gas. In Hamilton, Ontario, the provincial and Canadian governments are observing six test buses that were modified for spark-ignited methane last year.

Either spark-ignited or compression-ignition methane engines could be produced as original equipment for trucks. The engine makers—including major truckmakers plus Caterpillar Tractor (Peoria, Ill.) and Cummins Engine (Columbus, Ind.)—have so far shown minimal interest in supplying methane engines since there is no market demand to justify their development costs. But they are major targets for the natural-gas industry's lobbying efforts. Whereas in the 1970s the industry pushed the economy and abundance of methane compared to oil-based fuels, now it is selling natural gas as a way of meeting emissions standards. The Gas Research Institute (Chicago) recently began doing its own research on methane-fueled diesels, and it is planning to sponsor educational conferences for engine companies. Meanwhile, some gas utilities are operating dual-fuel fleets to demonstrate the concept: Columbia Gas in Columbus, Ohio, for instance, runs 19 methane/diesel dump trucks.

Regardless of its advantages, methane must overcome considerable market inertia.

Until engine manufacturers lend their backing to the concept, dual-fuel engines will continue to come from aftermarket conversion kits that cost about $1500–$2000, plus another $2000–$3000 for the heavy-duty cylinders that carry the methane. Leading suppliers are Controlled Fuel Systems, East Coast Conversions (Martinsburg, W.V.), and the Italian company B&B Engineering of Bologna. In Canada, where an alternate fuel policy encourages methane use, prominent engine converters are Fiba-Canning (Agincourt, Ont.), and the Vancouver companies Cryogas, Mogas, and Pro-Staff Fuels.

Regardless of its advantages, an alternate fuel must overcome considerable market inertia: Conventional diesel power has been embraced by truckers for decades. But advocates such as Bryan Memmott, president of East Coast Conversions, point out that the dependability of methane engines has already been proven in nonvehicle applications. "Large, 1000- to 3000-horsepower stationary diesel engines using dual fuel have operated reliably for years," he says. Many western Texas oil wells rely on them to power pumps, for example, and farm irrigation systems likewise use methane-fueled diesels. "The trick to turning them into a mobile, automotive technology," says Memmott, "is now a matter of successful marketing."

But the technology would need a widespread refueling network. In the U.S. today only about a dozen public stations offer natural gas, while about 300 privately owned compressor stations support individual fleets. The natural-gas industry argues that with its extensive natural-gas distribution network for residential and commercial use, vehicle refueling stations could be easily provided. But even though the pending emissions standards have many truck engineers stymied, notes Larry Strawhorn, head of engineering activities of the American Trucking Associations, they have yet to begin working with alternate fuels. Still, they haven't ruled them out either, he says.

Natural-gas trucks have the brightest prospect in countries such as New Zealand, where other methane vehicles are already popular. In 1977, New Zealand instituted a policy to convert about 20% of its vehicles to natural gas; today more than 70,000 operate there. Similarly, the Canadian government is backing a drive to convert some of the country's vehicles to methane. To assure an adequate refueling network, the government pays $50,000 (Canadian) subsidies to any filling station that installs a natural-gas refueling pump.

In the U.S., "federal support will be the ticket to attracting automotive manufacturers to produce natural-gas vehicles and really get the market rolling," says Wallace Parker, marketing manager for the methane advocate Brooklyn Union Gas. Such backing does not seem imminent, however. Donna Fitzpatrick, the Department of Energy's assistant secretary for conservation and renewable energy, concedes that alternate-fuel use in transportation has been low. But beyond applauding development by the private sector, she offers no indication of formal government backing. Thus, for the short term, the 1988 diesel pollution standards may be the biggest boost the methane vehicle industry is likely to get.

Jeffrey Seisler, manager of Natural Gas Vehicle Market Development for the American Gas Association, is an energy analyst and freelance writer.

TILT-ROTOR AIRCRAFT RISE TO THE OCCASION

Versatile hybrids of helicopters and planes could see civilian as well as military use

Tests of the XV-15 at NASA's Ames Research Center have helped demonstrate the suitability of the tilt-rotor helicopter-plane for military missions.

A new era is beginning in vertical and/or short takeoff and landing (V/STOL) aircraft with development of the "tilt rotor." Combining some of the best features of airplanes and helicopters, the tilt rotor is essentially a turboprop airplane that can take off, land, and hover like a twin-rotor helicopter. It obtains this versatility from a pair of movable helicopter-like rotors mounted on pylons at the end of its stout, compact wings. Powered by the interconnected turboshaft engines located alongside the rotor installations, each set of rotor blades rotates horizontally for helicopter-like takeoffs and swivels forward for high-speed flight.

Bell Helicopter Textron (Fort Worth, Tex.) and Boeing Vertol (Philadelphia) have teamed up to start building a small fleet of state-of-the-art tilt rotors, named V-22 Ospreys, for the Naval Air Systems Command. Their seven-year, $1.7 billion contract—signed in May—calls for developing a wing, a rotor, two fuselages, and an engine section for ground testing, and for building six flying prototypes. In addition to giving these contractors the chance to bid for a follow-up production contract to build more than 1200 Ospreys for the military, this program also allows them to explore the use of tilt rotors for civilian aviation in the crowded airspaces around major cities.

The tilt rotor has far outpaced rival types of hybrids in the race to fulfill the military's need for a transport helicopter with the range and speed of a turboprop. The tilt wing, for example, had several drawbacks in its helicopter mode. The X-wing, with rotors that can double as wings, is feasible, but is only now approaching the experimental aircraft stage (HIGH TECHNOLOGY, Nov. 1985, p. 68).

by Craig Schmitman

When the Osprey makes its first flight in June 1988, it will become the third generation of tilt rotors to take to the air. The development of tilt rotors has followed an evolutionary, rather than revolutionary, course, with each new generation incorporating lessons learned from the performance of its predecessor. Bell built the first generation—a pair of demonstrator craft carrying the designation XV-3—in 1953, in response to a U.S. Army request for a medical evacuation craft. Although they successfully converted from helicopter to airplane and back 125 times, those experimental machines had several problems. Even carrying just fuel and a single pilot, the piston-engined craft could scarcely get off the ground. Their large, slow-turning rotors created a destabilizing resonance with the relatively flexible wings. And because the mechanical control systems for the rotors were located in the fuselage, far from the pylons holding the rotors, the craft handled sloppily in flight.

Despite this lack of precision, pilots found the XV-3s relatively comfortable to fly for an experimental craft. And once aloft, even though underpowered, the craft achieved a maximum speed of 184 mph—an impressive effort when compared with the 70–80 mph at which the helicopters of the time topped out.

Engineering research continued after the program officially ended in 1966, and in 1973 Bell won a $28 million contract from NASA's Ames Research Center and the Army's Air Mobility Research and Development Laboratory (both at Mountain View, Cal.) to build two proof-of-concept tilt-rotor craft, designated the XV-15. "What we wanted to do was put together an aircraft that would demonstrate that we had overcome the deficiencies of the XV-3," explains Ron Reber, Bell Helicopter's manager of the XV-15 program.

By May 1977, when the XV-15 made its initial hovering flight, the capabilities of tilt rotors had undergone a profound transformation. The XV-15's wings were stiff enough to damp out

AUTHOR/AVMAR PRODUCTIONS

resonance. The advanced design of its rotor blades increased lifting power considerably. Its turboshaft engines, which were not available when the XV-3 was built, provided high power at a minimum cost in weight. And placement of the control actuators outside the fuselage and close to the pylons overcame the problem of sloppy handling. The craft reached speeds of 345 mph in level flight. It managed vertical takeoffs carrying over 3000 pounds of useful load, and short takeoffs with over 5000 pounds. What's more, the performance came at a bargain price. "It was supposed to be a minimum-cost program," recalls Bell's Reber, "so we used off-the-shelf equipment wherever we could."

The proof-of-concept XV-15 not only verified the basic tilt-rotor idea; it even proved suitable for military missions that tilt rotors were never intended to fly. In Navy-funded tests in 1982–83, an XV-15 simulated search and rescue missions, nap-of-the-earth flights (in which a craft flies close to the ground to avoid radar detection), shipboard operations, and in-flight refueling.

Thus, when the Department of Defense (DOD) in 1981 examined different VTOL aircraft—compound helicopters (in which jet engines provide horizontal thrust), pure helicopters, lift fans, and tilt rotors—for their ability to fulfill a wide variety of military missions, it judged the tilt rotor as the concept most likely to succeed. In fact, the department essentially created its own tilt rotor, says Tommy H. Thomason, Bell's director of tilt-rotor programs. As defined, the V-22 Osprey will travel 2100 nautical miles nonstop against a 20-knot headwind without refueling, at a cruising speed of over 300 miles per hour at almost 30,000 feet, carrying a payload of 10,000 pounds inside the fuselage or 15,000 pounds outside. It will also be able to fold its wings and rotors in winds as high as 60 knots for storage aboard ship.

The Osprey's fuselage and rotors will consist of advanced composite materials, which provide the strength and stiffness necesssary to maintain stability in flight while reducing weight significantly. Fly-by-wire electronic controls built by General Electric (Binghamton, N.Y.) will give the tilt rotor triple redundancy in case of damage in action. By replacing complex mechanical systems, the controls will simplify maintenance. Cross-shafting between the two 6000-shaft-horsepower Allison engines, which makes each engine responsible for 50% of each rotor's power, will keep the craft in control even if one engine fails.

A wide variety of missions can exploit those capabilities. The Navy, for example, wants 50 aircraft for combat search and rescue, and an additional 300 for antisubmarine warfare. The Marine Corps requires 552 combat assault and assault-support aircraft. The V-22 "has literally twice the speed of the helicopters we're working with right now, so your exposure is considerably less," explains Marine Corps Col. H.W. Blot, V-22 program manager for the Navy. "Instead of having to go through or over the enemy, you can go around him." The Air Force needs 80 aircraft to replace its aging fleet of HH-53 helicopters in transporting strike teams over great distances. And the Army plans on using 231 of the aircraft to provide logistics resupply, utility, and medical evacuation services.

The British experience in the Falklands war of 1982 illustrates the advantage of an aircraft with the range, speed, and lifting ability of the Osprey. "The British ships largely had to come in very close to shore to launch all of the troop assaults," explains Thomas N. Flanary, Bell's V-22 flight-test program manager and former commanding officer and chief test pilot of the Naval Air Station at Patuxent River, Md. "While they were that close to the Falklands, they were hammered significantly" by Argentine air assaults. Had the British been able to operate long-range V/STOL aircraft like the V-22, contends Flannery, "they could have launched from 200–300 miles east of there and been out of range all the time."

While the DOD was completing the study that defined the V-22, Bell Helicopter and Boeing Vertol, the world's two most experienced tilt-rotor companies as a result of contract work and engineering studies, teamed up to bid for the development contract—which they won without opposition. To stimulate eventual competition between the two companies for production of the tilt rotors, the DOD has specified that they split assembly of the six prototypes evenly between them. Target date for delivery of the first production craft is December 1991.

The contract has sparked some controversy. A study by the House of Representatives' Armed Services Committee questioned whether the Navy and Marine Corps had fully considered alternatives to the tilt rotor, such as existing or retrofitted helicopters, in defining their needs. And questions have arisen about the Bell/Boeing Vertol team's ability to meet the V-22's objectives for weight and performance. But supporters of the Osprey argue that these specifications are based on data collected in flight tests of the XV-15. Scaled-up wind tunnel tests on models of the Osprey "correlated very well," says Blot, "giving us a high degree of confidence that we know what the performance of the full-scale airplanes is going to be."

A strong performance by the Osprey may well lead to civilian versions of the tilt rotor. The incentive is that the air transport systems of some regions of the U.S., particularly the Northeast, suffer from serious congestion. "The New York City air traffic area represents the busiest hub in the world," says Roy Lobosco, supervisor of the Aviation Technical Services Division, Port Authority of New York and New Jersey. "Last year we handled some 78 million passengers, and for 1995 we're projecting 115 million." Two new studies are exploring the possibility that tilt rotors might handle significant amounts of this extra traffic, thereby relieving overburdened airports.

One tilt-rotor study, launched by the Port Authority in January, is an effort "to come up with a new system that could operate independently of the existing airports," says Lobosco. The stimulus was the fact that tilt rotors seem to have overcome the commercial shortcomings of pure helicopters, such as low speed, high fuel consumption, and uncomfortable interior vibrations.

Looking at the commercial viability of a civilian tilt rotor from a broader perspective—"to assess its potential benefits to the nation," according to David Ostrowski, rotorcraft program officer of the Federal Aviation Administration (FAA)—is a joint study started in April that involves the FAA, NASA, and DOD.

The FAA will examine certification criteria for tilt rotors and predict the likely impact of the hybrid craft on the

national air traffic control system. The agency will also try to determine how best to use the tilt rotor's special capabilities—by providing facilities such as public-use, all-weather heliports in 25 city centers by the year 2000, for example. The DOD wants to encourage a larger industrial manufacturing base for common types of tilt rotors to increase the country's potential capability for building military versions. NASA will examine technology spinoffs, determining what other aviation programs might benefit from the advances in materials, rotor design, and controls that have improved the tilt rotor. For example, Boeing Commercial Airplane (Seattle) might be able to adapt the composite construction techniques that it will use to build the Osprey's fuselage to fabricate composite wings for its newest prospective airliner, the 7J7.

Boeing will take part in the study, using its sophisticated market analysis system to look at the global marketability of various sizes of tilt rotors. Boeing Vertol and Bell Helicopters will provide Boeing (the parent company of Boeing Vertol) with performance specifications. Bell will analyze the operating costs and performance of a 16-passenger civilian tilt rotor to serve as a small commuter aircraft or a company airplane. Boeing Vertol will analyze two ways in which the Osprey can be adapted to civilian use—by largely cosmetic changes, such as eliminating its wing-folding mechanism, or by such major alterations as pressurizing and widening the fuselage.

The civilian market for tilt rotors will eventually reach 3000–5000 aircraft—and exceed the military market—according to John Zuk, chief of advanced plans and programs at NASA Ames. And demand will extend far beyond busy urban corridors in industrialized countries. Developing nations like Brazil and Indonesia, with limited numbers of paved airport runways, will also provide prime markets for a civilian tilt-rotor industry. Such opportunities are not being ignored by other aircraft-manufacturing nations. The French company Aerospatiale has carried out wind tunnel tests of tilt rotors, and the Soviets are believed to be working on their own design. "If the U.S. does not exploit this technology," warns Zuk, "certainly other nations will." □

Craig Schmitman is a Los Angeles–based aviation photographer who frequently writes on aerospace topics.

PERSPECTIVES

Technology pilots a course to America's Cup

U.S. yachting syndicates are enlisting technology in next year's battle to recapture the hallowed America's Cup, lost to Australia off Newport, R.I., in 1983. To boost their chances, the backers have enlisted research institutions and aerospace and automotive companies, as well as corporate sponsors for financial support. The six syndicates—America II (New York), Courageous (Newport, R.I.), SailAmerica (San Diego), Heart of America (Chicago), Eagle (Newport Beach, Cal.), and Golden Gate (San Francisco)—will spend a total of about $60 million to design and build the yachts. The challengers are anxious to recapture the Cup, which had rested undisturbed at the New York Yacht Club for 132 years—the longest winning streak in any sport. "Much more effort is going into the design," says Bill Langan, chief designer for the club's America II syndicate. "Budgets are generally in excess of a million dollars, which we've never approached before."

A few syndicates are designing several yachts. Some are natural progressions from previous America's Cup experience, others will be more experimental. The U.S. yachts will first compete against each other and against contenders from Europe, Canada, and New Zealand. The winner will then challenge for the Cup against the defending Australian 12-meter yacht.

The term "12-meter" refers not to the actual length of the yachts but to a formula to which the designers must adhere. Much simplified, the formula demands that the yacht's length plus the square root of its sail area be the same for all contenders; a longer yacht must therefore have smaller sails. Since both length and sail area add speed, the designer faces a tough choice and must consider factors such as probable wind strength, sea conditions, and the need for maneuverability. *Australia II* took the America's Cup with a very short boat and a large sail area—a design chosen for the light winds of Rhode Island Sound. Next year, the races will be off Western Australia, where the winds are generally stronger and the seas choppier.

Computer-aided design and simulation are helping to devise new yacht concepts (such as the America II, *shown here) in hopes of regaining the America's Cup.*

JAMES POZARIK

The trend in yacht design is thus toward longer, more stable boats with less sail area. Underwater shape is also critical. The keels of most of the new 12-meter craft are expected to sport winglets (extending fins) similar to those used by *Australia II.* When the yacht is heeling (tilting to one side), the uppermost fin acts like a wing to provide more lift. The heeling digs the lower fin deeper into the water, helping the yacht maintain forward momentum when sailing to windward.

Even though winglets were an American invention—developed at NASA-Langley—their potential was overlooked in past Cup races. Some designers were aware of the innovation but felt it could not be applied to the 12-meter keels without slowing the boats under some conditions; it took *Australia II,* with assistance from Dutch naval architects, to prove the winglets' advantage. Until recently, U.S. designers were not encouraged to experiment, says David Pedrick, a designer for the San Diego Yacht Club's SailAmerica syndicate: "A very low priority was put on hull development. The synergy needed for a progressive campaign was bogged down by complacency." Needless to say, the loss of the Cup changed those attitudes.

To predict the yachts' speed, designers are using computer "flow codes"—modified versions of those used in the aerospace industry—which measure the forces on a hull by treating it as a multifaceted surface. The America II syndicate is using a code written by John Hess, a research fellow at McDonnell Douglas in Los Angeles, and run in tests by Atlantic Applied Research (Burlington, Mass.). The three America II hull designs were optimized on an IBM mainframe computer by simplifying them as 5000 joined flat panels. The code "works fine, assuming the surface of the water is a solid wall," says Hess. This assumption is not entirely valid, however, because the yacht's motion creates its own waves. Additional program modifications are needed to account for this and other factors special to sailing.

The SailAmerica syndicate developed designs for its 12-meter, *Stars and Stripes,* with flow-code assistance from Science Applications International (SAI–Annapolis, Md.) and aerodynamics involvement of Boeing, Grumman, and United Technologies. Flow-code data were processed on Cray 1M and X-MP supercomputers and visualized with a graphics program developed at Brigham Young University.

Sailing represents a special challenge to scientists in aerodynamics and hydrodynamics because it occurs at the boundary of two fluids. Fluid dynamics usually models bodies in the simpler circumstance of being uniformly surrounded by either air or water. "But here there's an interface between air and water, and we're operating on that interface," says Langan. The drag of the hull through the water must also be considered, although most flow codes ignore this factor. The America II design team worked briefly with GM's Cadillac Division regarding its experience in drag reduction for cars; NASA's research on reducing drag on the Space Shuttle during reentry has also been applied to the 12-meter boats.

Sea waves add another complication that until now has been ignored in yacht model testing, partly because it is so difficult to simulate the effect of waves and partly because Newport waters are usually rather calm. Four American syndicates performed towing-tank tests using one-third-scale models designed by Offshore Technolo-

gy (Escondido, Cal.) to evaluate their behavior while heeling. For some syndicates, says president Rod Edwards, the company performed the tests in simulated wave conditions. At another towing-tank facility—Traco Hydrodynamics (Laurel, Md.)—president Eugene Miller says that more configurations have been tested for an America's Cup 12-meter yacht than for a U.S. Navy destroyer. The America II team has also used computer programs developed at MIT's ocean engineering department to study ship motion in waves, and wave interactions with offshore structures such as oil platforms.

But it will take more than speed to win the America's Cup. The races take place one-on-one, with one boat allowed to slow the other—for example, by blanketing it from the wind. This type of dueling, known as match acing, demands great maneuverability and acceleration in addition to speed. The longer boats being planned for the 1987 competition naturally turn more slowly, so designers are experimenting with underwater shapes that will reduce the turning time. The SailAmerica syndicate is thus being advised by Peter Lissaman, vice-president of aeroscience at AeroVironment, the company that developed the man-powered aircraft called the *Gossamer Condor*. According to Lissaman, a turning hull displacing large quantities of water poses fluid dynamics problems similar to those faced by lightweight planes.

While the primary goal is to regain the Cup, there are other payoffs for the companies involved. Staff members of large defense contractors relish the unique and challenging engineering problems, for example. And the small consultancies and specialist firms enjoy their moment in the Cup spotlight. "We are perceived by prospective customers as being at the leading edge of technology," says Lissaman. □

—Hugh Aldersey-Williams

Third world demands satellite slots

Certain parts of the geostationary orbit (GSO)—the band of space 22,300 miles above the equator where satellites hover above earth—are getting crowded. It already contains about 140 communications satellites, and several dozen more are being planned.

The traffic jam is of major concern to the world's developing nations, many of which fear that choice GSO slots will be filled before they are able to launch their own satellites. In that case, they say, they will be forced to either adopt costly new technology for their satellites or settle for positions that reduce the strength of the signal. And even though satellites can be spaced closer in the GSO—by using narrower beams, for example, and simultaneously transmitting multiple messages on one frequency—third world nations are seeking procedural changes as well as engineering fixes.

In the early years of communications satellites, the International Telecommunications Union (ITU), a Geneva-based arm of the United Nations, granted positions and frequencies on a first come, first served reservation basis. Discontent with that approach surfaced in the 1970s, when developing nations started planning their own satellite communications and direct broadcasting systems. An international conference in 1979 agreed on efforts "to bring about equitable access in practice." Nevertheless, in 1982, India—at the time a GSO newcomer—found itself bargaining with the Soviet Union, which had already staked out the position eyed by India.

Many developing countries argue that they are essentially being locked out of the program by the advanced nations. The segment of the GSO band from 0–45° east longitude, for example, is the most favorable for African satellites, but that region is already packed with 26 satellites beaming down to European nations; attempting to crowd in even more could result in beam interference.

Third world discontent surfaced last summer in Geneva at the first meeting of the World Administrative Radio Conference (WARC) on the use of the geostationary orbit. India contended that the first come, first served policy could avoid orbital congestion only if satellite owners used the most expensive and sophisticated technology. And the prior reservation of orbital positions and frequencies "is indiscriminate and catastrophic," complained Kenyan representative Stanley Malumbe, "serving as a self-fulfilling prophecy that developing nations will never be involved."

Delegates from the developing nations called for a new reservation system in which specific orbital slots will be set aside for individual nations or groups of nations. WARC delegates decided on a limited *a priori* reservation scheme that will permit each nation to satisfy its requirements for national services from at least one orbital position, within a predetermined position of the GSO and designated frequencies. ITU is now developing an allotment plan for GSO positions, using frequency bands in which no satellites are now transmitting, that will be presented at the next WARC in 1988.

The call for new rulemaking takes place against a background of new technology designed to improve the efficiency of satellite usage. For example, a process called dual polarization permits satellites to transmit two messages on the same frequency without interference; in essence, the signals are sent perpendicular to each other. Spot beams allow multiple use of the same frequencies to ground receivers, as long as they are separated by more than the approximately 750-mile diameters that the beams cover on the ground.

Meanwhile, sophisticated satellites such as Intelsat VI will combine switching with multiple spot beams to relay information among ground stations. The high-frequency Ka-band (17–30 gigahertz), proposed for transmissions by two new satellites—one from Hughes and the other from NASA—has five times the bandwidth of the most common C-band satellites. Another advantage of the Ka-band is that it forms a narrower beam, allowing satellites to be packed more closely in orbit. Ka-band satellites also deliver smaller spot beams.

Those improvements should meet global requirements. A computer model developed by engineers at Comsat and Intelsat in 1984, using recent projections of demand for satellite-transmitted telephone, television, and data services, concluded that the supply of satellite transponders will meet demand through the end of the century, even in the most populated frequency bands.

Third world nations argue, however, that the Comsat-Intelsat study assumed rapid adoption of the advanced technologies—an assumption that may not be valid for all countries. The emphasis on technological uniformity also reinforces the concerns of some developing nations that their communications satellite strategies are being determined by more advanced nations. Nevertheless, as the 1988 WARC meeting approaches, it is clear that a process is under way that offers reconciliation between the economic and political interests in GSO. □

—Donna Demac

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—*Donna Demac*

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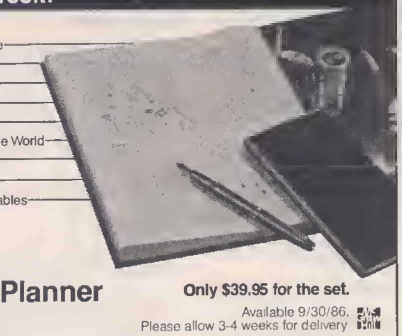

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TECHSTARTS

Zymacom:
VOICE/DATA NETS USE PHONE LINES

While lots of companies want to establish interoffice electronic communication, many local-area networks require installation of entirely new cabling systems. One alternative is using telephone wiring and a company's private branch exchange (PBX) as the network's backbone. Zymacom accommodates its network to the PBX and telephones a company may already own, adding the capacity to link personal computers as well. By adding combined telephone/display/keyboard units, it can also provide features such as electronic mail, voice messaging, and on-screen phone directories. The company is targeting small and medium-size companies and will compete primarily with PBX manufacturers such as Northern Telecom and the IBM subsidiary Rolm, whose top-of-the-line systems include similar capabilities.

Financing: $8 million in venture capital from General Signal, a manufacturer of industrial instrumentation.

Management: Founders Yohan Cho (chairman) and John B. Connolly (president) previously cofounded and headed Tau-tron, a maker of equipment for fiber optic, microwave, and satellite communications, which was acquired in 1982 by General Signal. Carl A. Carlson (VP of marketing) was a marketing manager for Digital Equipment, and Lawrence Beaupre (VP of manufacturing) was cofounder and head of manufacturing for Xyvision, a maker of computer-aided publishing systems.

Location: 2 Lyberty Way, Westford, MA 01886, (617) 692–4500.

Founded: February 1984.

JULIE HOUCK

Zymacom's Yohan Cho and John B. Connolly are aiming their interoffice voice/data network at small and medium-size companies.

Resonex:
MAGNETIC IMAGING FOR LESS

Magnetic resonance imaging (sometimes referred to as nuclear magnetic resonance) is considered the most effective way to see abnormalities in soft human tissue—and it doesn't expose patients to potentially hazardous x-rays. But the equipment's million-dollar-plus price tag makes this technology inaccessible to most hospitals and laboratories. Much of the expense, however, comes from the supercooling equipment and iron shielding required to operate the kind of magnets that produce the clearest images. Resonex reduces its machine's cost by using a less powerful magnet that needs no special cooling or shielding, yet produces clear images through computerized image enhancement techniques. It will be competing with GE, the industry leader, and with other large manufacturers such as Philips and Siemens.

Financing: $17 million in venture capital from investors including New Enterprise Associates, Cable House & Cozzad, and U.S. Venture Partners.

Management: Raymond Williams, Jr. (chairman, CEO, and cofounder), is a venture capitalist and also serves as chairman of Advanced Cardiovascular Systems. William Brody (president and cofounder) was director of the research laboratories at Stanford University, where he taught radiology. Robert Bock (VP of manufacturing) was a manufacturing manager for GE's Medical Systems Group. H. Dean Sutphin (VP of engineering and cofounder) was a VP for Halcyon Communications.

Location: 610 Palomar Ave., Sunnyvale, CA 94086, (408) 720–8600.

Founded: January 1983.

Ixys:
SMART POWER CHIPS

Just as microchips have replaced myriads of wires and switches in digital electronic equipment, they may soon take the place of voltage regulators in power conversion gear and mechanical controllers in an assortment of motion control devices. By connecting motion sensors to logic circuits, for example, designers at IXYS are making chips that can calculate the speed of a rotating motor shaft and—by automatically reacting to load variations—direct the motor to keep a constant speed. The company is targeting motion control applications in machinery such as robots and home appliances, and power conversion equipment like precision dc motors and high-voltage switches. Competitors include start-up Synektron in motion control chips, and Motorola and Siemens in high-voltage power chips.

Financing: $6.7 million in venture capital from investors including Adler & Co., Burr Egan Deleage & Co., Grace Ventures, Harvest Ventures, Oak Management, Stanford University, and U.S. Venture Partners.

Management: Nathan Zommer (founder, executive VP, and chief technical officer), Mark Barron (VP of engineering and operations), and Daniel Schwob (VP of marketing and sales) all came from General Electric, where Zommer was an R&D manager for the Intersil subsidiary, Barron was VP of R&D at the Calma subsidiary, and Schwob was a semiconductor marketing manager. Alan Hofstein (president) was president of electronic equipment maker Anatros and previously of EG&G Instruments.

Location: 142 Charcot Ave., San Jose, CA 95131, (408) 435–1900.

Founded: April 1983.

CLEANING UP IN HAZARDOUS WASTE

High volumes and tighter restrictions mean big business for disposal firms

Approximately 150 million metric tons of hazardous wastes were generated in 1981, according to the latest available Environmental Protection Agency data, and 300 million tons are projected for 1986 by brokerage firm Edward D. Jones (Maryland Heights, Mo.). This large and growing volume of hazardous waste, coupled with an increasing demand for safe and effective management of such materials, could create a market worth up to $65 billion over the next five years. Private industry is projected to spend about $40 billion of this total on waste treatment and disposal; some $10 billion will be provided by the Environmental Protection Agency's "Superfund" project, which pays for cleanup of certain existing sites; and an additional $15 billion could come from waste management programs undertaken by the Departments of Defense and Energy and state governments.

At present, most hazardous wastes are handled on-site by the companies that generate them. Disposal firms have concentrated on the remaining waste that companies want transported to off-site commercial facilities. This segment—even as a small proportion of a multibillion-dollar market—has been substantial enough to attract the attention of some of the largest businesses in the non-hazardous-waste disposal industry.

Moreover, opportunities for waste management companies will increase as federal regulations on dealing with toxic substances grow stricter, as required by the Resource Conservation and Recovery Act of 1984. The new rules are leading firms to obtain more professional management of on-site waste processing to begin contracting for an increasing amount of waste disposal off site.

by Alan F. Skrainka

The tighter rules have also led to increased restrictions on available land-based disposal capacity. It is difficult to obtain new landfill waste site permits, and some existing sites that fail to comply with federal groundwater monitoring and financial insurance requirements may be closed. Several states, moreover, have banned certain types of hazardous waste from landfill disposal altogether. As a result of these obstacles, disposal firms have begun to research alternative techniques for processing and storing hazardous waste, such as incineration at sea and advanced methods of chemical treatment.

These factors should lead an investor to seek companies with sufficient capital to acquire and expand waste disposal sites and to develop new disposal technologies. Three such firms are Waste Management (Oak Brook, Ill.), Browning Ferris Industries (Houston), and International Technology (Los Angeles).

Waste Management (NYSE: WMX), which operates 40% of the major hazardous waste sites in the United Sates, is the biggest force in the hazardous waste industry. Its predominance is built on the company's resource base of substantial earnings from domestic garbage collection (three-fourths of its revenue is derived from this market).

Waste Management has traditionally used off-site land disposal methods for dealing with hazardous wastes. But to avoid the difficulties of obtaining permits for new landfill sites, it is now exploring such options as incinerating PCBs and contaminated oil at sea, and expanding the capacity of some existing sites. The company also acquired SCA Services in 1984 to extend its operations to new areas of the country.

Waste Management had revenues of $1.6 billion in 1985, compared with $1.3 billion the previous year. Income and earnings per share also increased between 1984 and 1985, from $142 million to $171 million and from $1.46 to $1.72, respectively.

Browning Ferris Industries (NYSE: BFI) is a general waste disposal firm that participates in all aspects of the hazardous-waste market, including waste-spill and Superfund-site cleanups.

The company has been testing several techniques for improving the effectiveness of waste treatment and disposal. These include thermal destruction, which reduces the toxicity of waste chemicals by oxidizing them under conditions of high temperature and pressure, and the sequential batch reactor, which uses stress-acclimated bacteria to break down wastes into non-hazardous constituents. Browning Ferris has also erected an air-supported structure over a waste repository in Livingston, La.; this polyester-based canopy prevents rain from falling on the site and then seeping into groundwater, and can be easily removed when the repository is capped.

Corporate revenues totaled $1.1 billion in 1985, with income of $112 million and $1.60 earnings per share. Revenues in 1984 were $1 billion, with $89 million in income and $1.30 earnings per share.

In contrast to most firms in the industry, **International Technology** (NYSE: ITX), the largest company devoted solely to hazardous-waste disposal, has dedicated a majority of its activities to on-site disposal services. Anticipating a growing demand for on-site work, International Technology recently formed a new marketing group to target corporations in the chemical, petroleum, and utility industries with a full range of services, including analyzing samples from contaminated sites and constructing more sophisticated on-site disposal facilities.

The company had $143 million in 1985 revenues and $6.3 million in profits; the corresponding 1984 figures were $93 million and $4.5 million. Because of a rise in the number of shares outstanding, the 64¢ earnings per share in 1985 were slightly below the 67¢ earned in 1984. □

Alan F. Skrainka is a pollution control analyst with Edward D. Jones, a brokerage firm in Maryland Heights, Mo.

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In Horseheads, New York, Toshiba is taking another step in the right direction.

In 1985 Toshiba, one of the world's leading electric and electronics manufacturers, joined with the Westinghouse Electric Corporation to create a joint venture company called the Toshiba Westinghouse Electronics Corporation.

In 1986 this new company will start manufacturing color display tubes and color picture tubes in the little town of Horseheads, New York.

The tubes, which will be among the most advanced in the world, will be used not only in TV sets, but also in computer and other display terminals in offices, factories, homes and hospitals.

This project follows hard on the heels of other manufacturing projects Toshiba has already set up—electric motors in Houston, Texas, semiconductors in Sunnyvale, California, and color televisions and microwave ovens in Lebanon, Tennessee. It is, for Toshiba, another step in the right direction.

In Touch with Tomorrow

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